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ABSTRACT

The is the first report from a study of a structured active learning approach to an analytical chemistry course. The purpose of the study is to assess the longitudinal outcomes of this approach and to provide feedback to curriculum developers about the effects of the changes being made in the chemistry curriculum. The data, collected from a cohort of students in 1995, consists of open-ended interviews with students, open-ended student survey questions, Likert scale student survey items, and faculty and teaching assistant interviews. Two specific conclusions can be drawn from this study: (1) there is a number of longitudinal effects of structured active learning and (2) although it is possible to assert that the comparison group does not report the kinds of learning outcomes that the structured active learning students report, further study is needed to be sure that the findings are reliable. The survey instrument is appended. (DDR)

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Chem 110 Follow-Up Study Report #1

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Section 10

Chemistry 110 Follow-up Study Report #1

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1. Introduction

This is the first report of the Chemistry 110 Follow-up Study. The specific purpose of this study is to assess the longitudinal outcomes, if any, of the structured active learning (SAL) approach to Analytical Chemistry (Chemistry 110).[1] The more general purpose is to provide the New Traditions Leadership Team the kind of information they need to determine if the changes they are making in chemistry courses are resulting in sufficient value (in terms of improvements in valued types of student learning) to justify the costs in instructor effort and other resources. This first report of the Follow-up study focuses on the Spring 1995 cohort of students, whom we call the "Spring `95 Chem 110 alumni."

The objective of the analysis presented here is to answer the following main research question: Are there measurable effects, positive and/or negative, that SAL alumni report six-seven months after completing the course which reasonably can be attributed to the structured active learning method and that are not also reported by alumni of a comparison group? Our analysis tends to interpret the comparison course in terms of the characteristics of the SAL course. If the special features of the comparison course had been the focus of our study instead, and we had interpreted the SAL course in terms of the particular characteristics of the comparison course, a different set of findings would have resulted.

2. Research Design

The context of this study enabled us to develop a research design that is both context-rich enough to produce findings that are valid and meaningful, and generalizable enough to produce findings that are reliable and widely applicable. A key contextual factor is that the experimental group can be compared with a well-matched comparison group. The experimental group is comprised of students in Professor John C. Wright's Spring 1995 "structured active learning" (SAL) Chem 110 lecture section. Professor R. Claude Woods graciously agreed to allow the students in his section to be included as the comparison group. The two groups are well matched because:[2]

- there are no significant differences in terms of performance in Chem 109 (the prerequisite course) or distribution by gender;

- student self-selection into a particular lecture section does not explain differences in performance as evaluated by outside faculty assessors: while it is true that a higher proportion of the SAL students self-selected into this group, it appears that this does not explain the relatively higher average ranks given to SAL students than to comparison students because the SAL students who self-selected received slightly lower faculty assessor ranks than the SAL students who did not self select;

- observations of lectures and interviews with students during spring 1995 resulted in LEAD researchers concluding that each instructional method (Wright's structured active learning and Woods' responsive lecturing) was implemented at a high level of

competence, thus making it untenable to attribute any differences in student perceptions to this factor.

A second key contextual factor is that there is consistency over time in our findings about these two groups. A very substantial set of data collected during spring 1995 on these two groups of students provides a consistency check on the data collected during the follow-up study. The analytic constructs developed from the spring 1995 and the follow-up data are internally consistent.

2.1 Types of Data Gathered

Four types of follow-up data were collected to answer our question of whether, based on data collected from students six-seven months after completing the course, there are measurable effects that reasonably can be attributed to the structured active learning.

Open-ended interviews with students
Interview data were collected to provide context-sensitive information from which to develop replicable and valid constructs about how students perceived their Chem 110 experience 6 months later. For details of a qualitative analysis of these interviews, see Appendix A.

Open-ended student survey questions
On the basis of the interview constructs, we designed a survey (Appendix F) that includes 5 open-ended questions. This survey was administered to all Chem 110 alumni 7 months after they completed their course, and resulted in a 68% return rate. Data from the surveys are intended to test the reliability of the interview-based constructs when generalized to the full sample. For details of a content analysis of responses to three of the open-ended questions, see Appendix B.

Likert scale student survey items
The survey (Appendix F) also includes 34 items measured on a six-point Likert scale (where 1=disagree and 6 = agree). For details of a statistical analysis of a subset of these items, see Appendix C.

Faculty and TA interviews
In late November, five TAs and two faculty who were teaching Fall 1995 courses or discussion sections of the 1995 Chem 110 alumni were interviewed. Interviews lasted between 30 minutes and an hour. Instructors were told that some students in their classes had different types of teaching approaches the previous semester. They were not told what type of teaching approaches. They were given the students' names and asked to respond by characterizing each. The interviews were taped with interviewee permission, and later transcribed. The results of this data collection process are considered inconclusive because almost all the TAs and faculty interviewed had very limited interactions with the students, and thus were unable to assess features of their performance that might be a result of SAL or RL teaching methods. Accordingly, these data are not used in this report.

Accordingly, these data are not used in this report.

2.2 Data Analysis and Presentation

Our analysis strategy enabled us to use three types of data (open-ended interview, open-ended survey, and Likert scale survey) such that the strengths of each type compensate for the weaknesses of the other types.

- Open-ended interview data is context-sensitive. Qualitative analysis techniques enable analysts to interpret specific comments in a way that is properly "weighted" in light of the complex contexts in which the interviewees function (Coffey & Atkinson; Patton). For example, in analyzing the interviews, we found that the themes emerging from the SAL and the RL interviews were, in many cases, fundamentally different in nature. (The key features of each culture are outlined in the table of contents of Appendix A.) To provide a valid representation of the data, we chose to organize the data in a case study format, which allows us to present the key features of two different "learning cultures." Analytical constructs developed through qualitative analysis methods thus have high validity.[3] However, interview data are based on small sample sizes (due to the expense of both gathering and analyzing this type of data), may have weak reliability, and thus are less suited as a basis for generalization to the full population represented by each case study.

- Likert scale data are suitable for statistical analysis and thus have high reliability.[4] This type of analysis produces findings the reliability of which can be determined through statistical techniques (as described in Appendix C). By design, these statistical constructs provide comparative information about all groups within the population studied (in this case, SAL and RL student cohorts). However, such constructs are not strongly linked to the possibly diverse contexts of the comparison groups, and thus may not be valid when applied to any one group. Thus, while statistical constructs based on such data may be found to be reliable, there is less certainty that the constructs are valid if applied to particular contexts. In other words, they have low validity.

- Open-ended survey data are half-way between qualitative case studies and statistical analysis, in that they produce more context-sensitive (and thus valid) constructs than Likert scale data, and, being drawn from a large sample, are more reliable than qualitative analyses. For this study, we performed a content analysis of three of the open-ended survey questions, formulating a set of *post hoc* analytical constructs that enable cross-group comparisons. However, because the constructs were developed out of relatively context-sensitive open-ended responses, it is possible to assess the validity of each construct for each course culture. (For more detail on this analysis process, see "Analysis Based on *Post Hoc* 'Mentions': A Content Analysis Approach" in Appendix B.)

Seeking to use the best of each type of data, the analysis presented in Table 1 below is structured by the constructs appearing in the case studies (Appendix A). As noted above, these case study

questions (Appendix B) and Likert scale survey questions (Appendix C).

3. Findings[5]

Table 1 presents the results of this process of relating the three types of data. Each construct is labeled with either an "A," "B," or "C" plus a number, and refers to constructs presented in one of the appendices. Details on each construct can be located by consulting the referenced section of the appendices.

Table 1
Constructs Based on Interview Data Supported by
Constructs Based on Open-ended and Likert Scale Survey Data
Spring 1995 Chem 110 Alumni

A. Constructs Based on Interview Data
B. Constructs Based on Open-ended Survey Data
C. Constructs Based on Likert Scale Data

The Structured Active Learning Course Culture
A.1.1 Lasting Effects of Structured Active Learning
A.1.1.1 Taught the Value of Group Work
B.1.3.1.1 Understand Concepts Better
B.1.3.1.2 Friends
B.1.3.1.3 Voluntary Collaboration
B.1.3.1.4 Helps in sophomore classes
B.2.1 More Willing to Work with Others
B.2.2 Chem 110 classmates are in current work groups
B.2.3 Understand More
B.2.4 Working in Groups Helped Me Meet Others
B.2.5 Less Willing to Work in Groups
B.2.6 Positive Overall
B3.1 Labs
B3.2 Difficult Problem Solving
B3.3 Brainstorming
B3.4 Projects
B3.5 Homework
C.6.a Perceived Ability to Work in Groups (Men)
C.6.b Perceived Ability to Work in Groups (Women)

A1.1.2 Taught a Discovery Approach to Problem Solving
B. No relevant construct
C. No relevant construct

A1.1.3 Resulted in Confidence and Lasting Friendships

B.1.2 *Positive Effect of Professor*
B.1.3.1.1 *Understand Concepts Better*
B.1.3.1.2 *Friends*
B.1.5.1 *Positive Confidence*
B.1.5.2 *Negative Confidence*
B.2.3 *Understand More*
B.2.4 *Working in Groups Helped Me Meet Others*
C.2 Confidence

A1.1.4 Left a Need for Structured Group Learning

B.1.2 *Positive Effect of Professor*
B1.3.1.4 *Helps in sophomore classes*
B2.1 *More Willing to Work with Others*
B2.2 *Chem 110 classmates are in current work groups*
C No relevant construct

A1.2.1. The Dynamics of Functional SAL Work Groups

A1.2.1.1 Relationship between Group Work, Challenging Problems and Deeper Learning Accomplishments

B.1.1 1 *Challenging but worth it*
B.1.1.2 *Learned lots*
B.1.2 *Positive Effect of Professor*
B1.3.1.1 *Understand concepts better*
B1.4.1 *Positive connections*
B1.4.2 *"Negative connections" (almost no mentions)*
B1.6 *Positive overall*
B2.3 *Understand more*
B3 *Labs, difficult problems, and projects are better accomplished by student groups*
C1 Perceived Scientific Skills
C3 Agility
C4 Enjoyment of Science
C5 Perceived Ability to Connect Concepts and Applications

A1.2.1.2 Developed Valuable Group Skills

B2.1 *More Willing to Work with Others*
C6.a Perceived Ability to Work in Groups (Men)
C6.b Perceived Ability to Work in Groups (Women)

A1.2.1.3 Fun and Friends

B1.3.1.2 *Friends*
B1.6.1 *Positive Overall*
B2.1. *More Willing to Work with Others*

B2.2. Chem 110 classmates are in current work groups
B2.4. Working in groups helped me meet others
C No relevant construct

A1.2.1.4 Group Dynamics Are Both Complex and Productive
B1.1.1 Challenging but worth it
B1.3.1.1 Understand Concepts Better
B1.3.2 Group work dysfunctional
B1.5.1 Positive confidence
B1.5.2 Negative confidence
B2.3 Understand More
B2.4 Working in Groups Helped Me Meet Others
C6.a Perceived Ability to Work in Groups (Men)
C6.b Perceived Ability to Work in Groups (Women)

A1.2.2 The Dynamics of Dysfunctional SAL Work Group
B1.3.2. Group work dysfunctional
B1.5.2 Negative confidence
B.2.5 Less willing to work in groups
C No relevant construct

A1.3 Well-integrated Course Components
B1.2. Positive effect of professor
B1.4.2 Negative connections (almost none for SAL)
B2.6 Positive Overall
C1 Perceived Scientific Skills
C2 Confidence
C3 Agility
C4 Enjoyment of Science
C5 Perceived Ability to Connect Concepts and Applications

A1.4 Open-ended Group Labs
B1.4.2 Negative connections (almost none for SAL)
B3.1 Labs
C1 Perceived scientific skills
C5 Perceived ability to connect concepts and applications

A2 The Responsive Lecturing (RL) Course Culture

A2.1. Lasting Effects of Responsive Lecturing
A2.1.1 Voluntary Group Work
B.1.3.1.3 Voluntary collaboration
C No relevant construct

A2.1.2 Course Content Useful

B1.1.1 Challenging but worth it

B1.1.2 Learned lots

C No relevant constructs

A.2.1.3 A Few Lasting Friendships

B No relevant constructs

C No relevant constructs

A2.2 Learning Experiences Associated with the RL Course

A2.2.1 Students make connections

B1.4.1. Positive connections (no RL mentions)

B1.4.2 Negative connections (many RL mentions)

C4 Enjoyment of science (low RL score)

C5 Perceived ability to connect concepts and applications (low RL score)

A2.2.2 Learned how to study

B No relevant constructs

C No relevant constructs

A2.2.3 Repetition an important feature of the learning experience

B No relevant constructs

C No relevant constructs

A2.2.4 Lab and Lecture Should Be More Connected

B1.4.1. Positive connections (no RL mentions)

B1.4.2 Negative connections (many RL mentions)

C4 Enjoyment of science

C5 Perceived ability to connect concepts and applications

A2.2.5 Emphasis on Accuracy Led to Strong Lab Skills

B No relevant constructs

C No relevant constructs

A2.2.6 Degree of Connection with Professor Varied

B1.2. Positive effect of professor

C No relevant construct

A2.2.7 Group Issues

B1.3.1 Group work valued (almost no RL mentions)

C6a Perceived ability to work in groups (men)

C6b Perceived ability to work in groups (women)

A review of Table 1 indicates that certain SAL interview-based constructs are amply supported by survey-based constructs. We propose that these constructs are both valid and reliable. Other interview-based constructs--in particular, those from the RL case study--are not well-supported by survey-based constructs. This is to be expected, given that our research question is to determine what effects, if any, SAL alumni report six-seven months after completing the course which reasonably can be attributed to the structured active learning method and that are not also reported by alumni of a comparison group. Because our research was designed to focus on the characteristics of the SAL course, there is a strong bias toward interpreting the comparison course in terms of SAL characteristics.

To understand the effects of that the SAL method had for course alumni, it is best to read the case studies in Appendix A and then review the Appendix B and C constructs listed in Table 1 for each construct drawn from the case studies. Below we present this process for one of the SAL case study constructs, "Relationships between Group Work, Challenging Problems and Deeper Learning Accomplishments." First we reproduce the section in Appendix A that describes this construct. Then we present the constructs from the open-ended survey and Likert scale data which Table 1 lists as providing support evidence for the reliability of this construct.

Relationships between Group Work, Challenging Problems and Deeper Learning Accomplishments

Learning from peers is effective.
Many SAL students in functional groups stated that learning course material through group work increased their understanding. They explained that it was because their classmates could explain ideas to them at their own level that they understood more. Students expressed that when other students, rather than the instructor, explained ideas, it increased their understanding of the material. As their peers were at the same level, they felt more comfortable asking them "stupid questions." Students, in turn, learned by explaining to fellow students. Typical SAL responses are below.

> *They [the group] were actually kind of helping me learn what I didn't understand. We just kind of worked together explaining different things, and that actually helped us learn....That group learning actually did help me for that first exam.*
>
> ********
>
> *When he [the professor] actually had the groups go up to the board...and explain how they did [the homework problem], that actually did help out a lot. To kind of explain what was going on in lecture....When it's actually someone who's in the class, and my age, in the class I kind of listen to them more. For some reason I just kind of respect what they're doing more. Because they're going through the same thing I am. They'll understand more what I'm going through than the TA. The TAs, they had this a long time ago. What they know is way beyond what we know, and sometimes they explain it and it's more difficult to understand.*
>
> ********
>
> *A lot of the times, I know I wouldn't understand something, and someone else would, and*

they'd be able to explain it to me. Or, I would understand something that they wouldn't, and so I'd be able to explain it to them, and so I was able to understand things a lot better, than just trying to ask the professor one on one, or my TA. I was able to ask a friend, "Okay, I don't get it." And he'd be able to help me, or she, whatever...It was just easier cause it was more of a one on one situation, and it was easier to talk to a friend of mine that go to the professor, and [and say], "I don't understand this."

Challenging problems force group collaboration

Closely associated with students' perception that they learned more by working in peer groups is their perception that the problems assigned in Chem 110 were so challenging that were forced to work in groups in order to solve them, and that the result of this hard collaborative work was a deeper level of learning. When describing this complex experience, students also tended to communicate that they took great satisfaction in both the process and the resulting learning achievements. The following interview excerpts make this complex point.

It was a challenge, the whole course, and being in a group just helped you get by. I don't think I would have done it by myself, got through that class by myself.

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I kind of liked it, because I thought the problems were really tough that we were working with, and there was four of us in our lab group, and we got along really well, and so we were able to collectively work through the problems and get the right answers, so I really liked it.

****

I noticed that there was a couple of times when you know, especially when like people were calling me to get into groups that the problems, I would just look at them and I would be going "Oh my, this is insane." I mean I could swear to the fact that they were set up so that you almost had to work with about three people to figure out what was going on just because they were that difficult.

Group Work Associated with a Repetition that Results in Meaningful Understanding

Many SAL alumni described a special kind of repetition that they experienced in Chem 110. It was not a matter of "drilling in" an algorithm. Rather, it was a type of repetition that enabled them to comprehend the big picture while also understanding the nitty-gritty details. They described a type of repetition that takes place as groups of individuals work through challenging problems. This kind of repetition goes beyond memorization, and leads to making new conceptual linkages between theories and applications. Below are typical SAL quotes that make this point.

Plus with all the group work you were constantly going over the material over and over again. It was really ingrained, so that gave a little bit more confidence. ...Especially with the labs, in the group labs that we had to do, there was a lot of doing the same stuff over and over again and the same calculations over and over again, so that helped in just doing it, constantly doing it. You have to understand it and know it and know it really well.

****

Where I learn, is doing problems and seeing problems done, right in front of me and allowing me to interact too. That's probably the best way that I can learn...I understood what [the professor] was lecturing about, but for me to comprehend it, for me to actually get it in my brain, I had to actually do it myself and solve some problems by myself or with groups or on a piece of paper instead of just staring up at the board.

Deeper Level of Understanding through Valuing Multiple Viewpoints

SAL alumni explained that they came to value multiple viewpoints, the different things you learn from different people. They learned to "pool our knowledge together." These students explained that through peer interaction in groups, they achieved a deeper level of understanding. The students indicated that the problems in Chem 110 encouraged a number of approaches and through the group work the students realized, many for the first time, that different people think about chemistry in different ways. This was important to students for several reasons. Most students' previous chemistry teachers taught them to use specified procedures to solve certain types of problems and as such, provided little room for the students to develop their own approaches. They valued encountering students who approached chemistry differently from themselves. Below are typical SAL responses.

If a group could do it better than I could by myself, then definitely [I prefer working] with the group...If you don't understand something and start off going the wrong way, I mean, totally missing something, if there's something that you might miss conceptually, then you probably want to get together in the group so you don't miss it so that other people who would normally cover that point would still be there, and then another something that they missed somebody else would see or understand.

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When we did group work last year, it wasn't a give-take kind of think, it wasn't like one person gave and one person take, it was let's all pool our knowledge together.

Survey Constructs that Provide Supporting Evidence for the Reliability (Generalizability) of this Interview-based Construct

Open-ended Survey Question #18

B.1.1 1 *Challenging but worth it*

37% percent of the SAL survey respondents mentioned that the class was challenging, but worth it. (By contrast, 28% of the RL respondents mentioned this point.)

B.1.1.2 *Learned lots*

34% of the SAL survey respondents mentioned that they "learned lots" in Chem 110. (By contrast, only 11% of the RL students mentioned this experience.)

B1.2. *Positive effect of professor*

25% of the SAL survey respondents mentioned their Chem 110 professor as having a clearly positive effect. (By contrast, 9% of the RL students made this point.)

B1.3.1.1 *Understand concepts better*

This construct is one of four features of the more encompassing construct, "group work

valued." 24% of the SAL respondents mentioned one or more of the four features of this construct. (Only 4% of the RS respondents mentioned that they valued group work.)

B1.4.1 *Positive connections (real world connections and connections with current classes)*

9% of the SAL survey respondents had positive things to say about how Chem 110 helped them make intellectual connections. (By contrast, no RL students were coded as mentioning "positive connections.")

B1.4.2 *Negative connections*

Only 4% of the SAL survey respondents had negative things to say about their interest in making intellectual "connections" in Chem 110. (By contrast, 24% of the RL students were coded as mentioning "negative connections.")

B1.6 *Positive overall*

Of the SAL students, 32% offered comments that were coded as conveying an overall positive response to Chem 110. (By contrast, 11% of the RL students' comments were so coded.)

Open-ended Survey Question #15

B2.3 *Understand more*

Of SAL alumni who answered whether their Chem 110 experience influenced them to work in groups as sophomores, 16% said that it did because working in group helps them understand more. (In contrast 7% of the RL alumni offered this answer.)

Open-ended Survey Question #16

B3 *Labs, difficult problems, and projects are better accomplished by student groups*

Of the SAL alumni who answered the question, "What types of course work are better accomplished by student groups?" 47% mentioned labs, 34% mentioned difficult problems, and 13% mentioned projects. (In contrast RL alumni mentioned 11%, 28% and 11%, respectively.)

Likert scale survey questions

C1 Perceived Scientific Skills

This statistical construct was produced by creating a scale based on the answers to the following survey questions: "I feel the teaching method used in this course increased my skills in: a) problem solving, and b) experimentation," and "As a result of my chem 110 course I am: a) able to set up equations, b) able to set up an experiment, and c) able to solve equations." On this scale, SAL alumni scored an average of 4.66 out of a possible 6.0. By comparison, the RL alumni scored an average of 4.16.

C3 Agility

The "agility" construct was produced by creating a scale based on the answers to the following survey questions: "As a result of my Chem 110 course I am more willing to try other ways of thinking and learning," "As a result of my Chem 110 course I am more comfortable with learning in new ways," chem 110 made me feel more comfortable with cross-disciplinary ways of thinking," and "The course structure left me confused about what I was to know." (The last item was reverse coded.) SAL students scored 4.39 out of a possible

6; whereas, RL students scored 3.61 (Appendix C, Figure 3) .

C4 Enjoyment of Science

This statistical construct was produced by creating a scale based on the answers to the following survey questions: "Chem 110 engaged by interest and raised my enthusiasm for chemistry," and "Most aspects of chem 110 were intellectually exciting." Compared with RL alumni, SAL alumni scored higher on this scale ($p<.001$): 66% of SAL, compared to 29% of RL, students scored high on this measure (Appendix C, Figure 4).

C5 Perceived Ability to Connect Concepts and Applications

This statistical construct was produced by creating a scale based on the answers to the following survey questions: "Chem 110 helped me understand how to apply chemistry to real world issues," "In this course I discovered the value/use of concepts by utilizing them to solve problems," and ""In this course I was able to integrate what I learned in lecture and lab." Compared with RL alumni, SAL alumni scored higher on this scale ($p<.001$): 86% of SAL, compared to 21% of RL, students scored high on this measure (Appendix C, Figure 5).

C6 Perceived Ability to Work in Groups

This statistical construct was produced by creating a scale based on the answers to the following survey questions: "As a result of my Chem 110 course I am more interested in working with others to complete course work," and "As a result of my Chem 110 course I am more able to work with others productively." Compared with RL alumni, SAL alumni scored higher on this scale ($p<.05$). Interestingly, this effect could be primarily attributed to the different experiences of women ($p<.05$): 81% of SAL, compared to 36% of RL, women scored high on this measure (Appendix C, Figure 7). Although a trend toward greater perceived ability to work in groups was apparent among the men, it was not statistically significant ($p=.22$): 61% of SAL, compared to 38% of RL, men scored high on this measure (Appendix C, Figure 6). Of note, this survey construct relating to perceived ability to work in groups is the only one of the six constructs reported in Appendix C in which a gender difference was found.

4. Conclusions

Two overarching conclusions can be drawn from this study. The first is that there are a number of effects that SAL alumni report that can be attributed to the structured active learning method, and that are not reported by alumni of the comparison group. In particular, these are:

1) The SAL course has four types of lasting effects: teaches the value of group work; teaches a discovery approach to problem solving; results in increased confidence and lasting friendships; and leaves students experiencing a need for structured group learning in subsequent classes.

2) SAL students who had functional work groups stressed several characteristics of these groups, including: the productive relationship between group work, challenging problems, and deeper learning accomplishments; the value of developing group skills; that the course was fun and led to the formation of friendships; and that group dynamics are both complex

and productive.

3) SAL students who had dysfunctional work groups stressed several characteristics of these groups, including that groups tend not to be productive when: there is a "controller" or there are "slackers"; faster students have an ethic of impatience; slower students accept "spoon-fed" answers (as this leads these students to lose confidence); and members simply resist group work.

4) SAL students noted with strong approval that the course components were well-integrated; and

5) SAL students compared the open-ended labs very favorably to the canned labs.

The second overarching conclusion is that while the study of the comparison group made it possible to assert that comparison group students do not report the kinds of learning outcomes that SAL students report, a different study would be needed to be sure that the case study findings on the RL course culture are reliable.

Planned study of the spring 1995 Chem 110 alumni will provide information on whether these or other effects persist for through this cohort's junior and senior years. In addition, a forthcoming report on the spring 1993 and a planned study on the spring 1994 Chem 110 alumni will help determine if the effects experienced by the spring 1995 cohort are also experienced by these two earlier cohorts. These follow-up studies also will include data on persistence to senior year by major by sex for the SAL and comparison groups. To help determine whether students experience similar long-term effects of SAL Chem 110 when the course is taught by a professor other than John Wright, it may be worthwhile to study the spring 1996 or spring 1997 groups taught by Professor John Schrag.

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Endnotes

1.Detailed additional information about the evaluation study of the SAL approach to Chem 110 can be found in other reports and papers. Extensive qualitative data analysis focusing on the faculty goals and methods, and the TA and student experiences are presented in three formative feedback reports produced during Spring 1995. Papers that focus on the quantitative results of the faculty assessor component of the evaluation study are under review by *Science* and the *Journal of Engineering Education*. A paper appearing in the 1996 *Proceedings of the American Society for Engineering Education* meeting provides details on the evaluation methods used to study Chem 110 during spring 1995, while an article presenting details of course implementation is forthcoming in the *Journal of Chemistry Education*. For preprints of the *J. Chem Ed.* paper and the manuscript under review by *Science*, contact John C. Wright, Department of Chemistry, UW-Madison, WI 53706. The other documents may be obtained by contacting the LEAD Center, 1402 University Ave., Madison, WI 53706, (ph: 608/265-5920; fax: 608/265-5923).

2. The information supporting the statements listed below appears in the LEAD Center "Chem 110 Formative Feedback Reports" #1 and #3. See also the manuscripts under review by *Science* (Wright, et.al.) And the *Journal of Engineering Education* (Springer, et.al.).

3. "'Validity' designates that quality of research results which leads one to accept them as indisputable facts... We speak of a measuring instrument as being valid if it measures what it is designed to measure, and we consider a content analysis valid to the extent its inferences are upheld in the face of independently obtained evidence... Validation may be said to reduce the risk involved in acting on misleading research findings as if they were true." (Krippendorff, p. 155)

4. "Reliability assesses the extent to which any research design...and any data resulting from them represent variations in real phenomena rather than the extraneous circumstances of measurement, the hidden idiosyncrasies of individual analysts, and surreptitious biases of a procedure." (Krippendorff, p. 129)

5. Findings from survey responses on the effects of taking the Faculty Assessor oral exam are presented in Appendix D.

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Cases Studies of Two Course Cultures

The following two case studies were developed using content analysis of interviews. In early November 1995, six months after the Spring 1995 Chem 110 alumni completed Chem 110, LEAD researchers invited a relatively small sample of students from both the experimental and a comparison group for focus groups interviews. Numbers of students by lecture and sex appear in Table 1. While structured by a protocol (Appendix E), the interviews were open-ended. (For example, when a student raised a point, we asked them to elaborate, and encouraged dialogue among the students about the point.) The interviews varied in time from 45 minutes to almost 2 hours. The interviews were taped with interviewee permission, transcribed, and quickly analyzed during November 1995.

Table 1
Interviews by Lecture and Sex

	Students Scheduled for Interviews			Students Actually Interviewed	
	SAL	RL		SAL	RL
Male	13	7		8	4
Female	8	11		2	3
Total	21	18		10	7

1. The Structured Active Learning (SAL) Course Culture

1.1 Lasting Effects of Structured Active Learning

What effects of Chem 110 did SAL interviewees perceive as persisting for them six months after they completed the course? Listed below are key constructs about the lasting effects of SAL. Chem 110:

- taught the value of group work
- taught a discovery approach to problem solving
- resulted in confidence and lasting friendships
- left many feeling a need for a structured group learning process because they wanted, but were not always able, to establish effective voluntary work groups on their own.

1.1.1 Taught the Value of Group Work

A few students expressed that they discovered the value of groups. Below is a typical SAL quote.

> *I found out that groups are the only things that get things done some times. I don't mean all the time. But, looking at the kinds of problems we did in the lab, they would be - I think both of them were actually, "Here's a problem. We want you to create a process that's going to make this thing work." I was finding out that when you get past a certain level like that you almost have to work in a group like this to get a procedure like this made, perfected, and understood. And coincidentally enough, this is what they do in industry today...Granted we are doing something on a basic level that has been done hundreds of thousands of times, obviously. But for us it's the sort of new thing. What we're really doing there is we're doing research and we're saying, "OK. Let's make this procedure." If you just look at yourself, unless you're going to spend a year or two on it, you just kind of go, "Where do I start?" It's having three or four heads together saying, "Let's look at each piece of it" and having every-body sort of collaborate on it that really makes it happen. That's just the way it is in industry because you have to do it that way.*

1.1.2 Taught a Discovery Approach to Problem Solving

Many students commented that the problems assigned in Chem 110 helped them develop a discovery approach to problem solving. They described learning how to take pleasure in a figuring out why things work as they do and really understanding the answers to problems, rather than just "getting" answers and leaving. They were pleased and sometimes surprised to find different ways to solve problems beyond memorization and plug and chug to being able to see things from "more than one angle." Below are typical SAL quotes.

> *But [Chem 110] changed the way as a student, that I study things. I don't simply go for an answer because it's the one given to me in the back of a book. And I say "Well, this is what I need to get because this is what the rest of the world agrees on." You tend to justify things with how you do it. You don't just simply say, "This is the answer either a) because someone else said it was, or b) because I think it is." I back things up now. I say, "Well, I got this example that says it's true and here's something else that agrees with me and look at this too." I tend to back things I'm doing up a lot more with other ideas now, rather than just spit something out.*
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> *To the point of doing problems. I attack them differently, in terms of looking at problems, reading into them, and figuring out - at least having the patience to find out different ways to solve them.*
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> *******
>
> *[The course] made me think more, not just accept why things happen, but think about how they happen. Like why does the top of your car get hot when the sun shines on it. Kind of*

one of those things. So it gives me more of a "Why?" mind, [rather than] just accepting it.

****

So you have a method of going at it, solving a problem, instead of just blindly attacking it. That kind of helps me now, cause I look at a problem and think about what you do first, instead of just going at it.

****

Now I'm back [in] labs and in physics we're doing the same old, find out what the answer is, draw some conclusions, and you're done....But, like my TA in physics has told me a lot of times, "Boy, you really want to know a lot about this." I don't just do labs anymore to get the answer. And a lot of people that are taking physics 201 are in this kind of mode where it's like, "I want the answer, I want to leave early." And that's what they're doing. And me - I'm sitting there going, "Well, wait a minute. There's more to this. What's going on here or here?" That way I do get a lot more involved in labs.

1.1.3 Confidence and Lasting Friendships

Confidence. A few interviewees reported that Chem110 increased their level of confidence. Confidence comes from succeeding in a very challenging class and confidence can come from the professor. Typical quotes include:

But I think that just the overall experience gave me the confidence I think that I needed, because it was so challenging, and I actually could do a lot of it. So it was rewarding in that sense, and I think that in the future I can look back on it and say, well that was a pretty impossible class, but I could do it. I could probably do this also. So I think it was just really useful for a confidence builder.

****

I think [SAL professor] made it very possible for every student to succeed in the class. And I think that's the kind of guidance that freshmen need. And it's something that I needed desperately at that time in my life...I really valued the fact that he cared so much about and made it possible for us to succeed and that is the kind of thing that freshmen more typically need than other, like upperclassmen. Because by then they should probably either have or not have the tools to do that.

Lasting Friendships. Many SAL students mentioned that they are still friends with other students from their Chem110 class. A subset of students even mentioned that they liked the grouping of students by major. Below is a typical SAL quote.

I remember my lab group a lot. We had a lot of fun, and we met outside of class a lot. A lot of the people in my lab group are my best friends right now. So that's pretty good. That's one of the positive things. We just got really lucky. He made the lab groups according to what interests you were in, so most of the pre-med students were in my lab group, and most of the engineers were in a different one. I thought that was a really good idea, and it ended up to work out really well because most of the med scholars in the class

were in our lab group, so we got to know a lot more of the med scholars. We had a lot of fun with the people when we weren't doing chemistry, so I thought that was really a good part of the class.

1.1.4 Left a Need for Structured Group Learning

Many expressed a need for the structured group learning process they had in Chem 110. A few students described their efforts to establish effective voluntary work groups in their sophomore courses. These reported inconsistent success in reproducing the processes. Below are typical SAL quotes.

I still work with a couple of my lab partners when I do my homework, from last semester even.

****

I found it really good because I got a chance to work with different people. Even in the labs and for the projects and outside class, it's a good way to discuss things, especially since, I found the material challenging, so I don't think I could have understood everything all by myself...seeing how what happened last semester, I'd like to if I can, continue the same group study this semester too. The professor doesn't have to do it. Just in my class, get together with a group of friends and study the same subject...

****

Last year I didn't like it at all. I don't like working in groups very much, but it's kind of helped for classes this year cause now if I want to I can...If I want to work in groups it's a lot easier for me to just find a group and get some work done. But I still like working by myself or just with one other person better because we kind of get more done and I understand more.

Others reported wanting, but being unable, to establish successful groups without the formal organization or assistance of the professor. Collaborative learning, in most cases was either simply absent from, or discouraged by most professors. It was therefore up to the students to organize work groups if they wanted them. Below are typical SAL alumni quotes.

I miss what Chem 110 was doing for me in the group interactions some times. I'll be looking over problems in physics and I'll be, "Gee, I wish I knew about two people right now that I could call up and do this with." But they're not really there like they were and it's hard for me as a person to just go out and find these people and say, "Look, I want to do physics right now." But it's just something I miss--that I'm not getting this year.

****

I think what happened was after 110 I kind of went back to the way things were because I'm in this type of class again where it's just pretty much, "Well, if you want help we're here." And I go to office hours and that, but it's definitely not the same as when I'm saying, "OK, we're going to have eight of us over at the library." I mean I was in two study sessions last year where I was called on the phone and asked over. And that had

never happened to me before. That was just unheard of for me. I was like, "Of course I'll come."

****

[The professor] walks in with the assumption that you are working alone and that you intend to work alone....But I came into math immediately this year saying, "OK. Where's the groups? Who can I work with problems with other people?" And it's pretty much "No, no, we don't want you to do that. Just do it the way we want you to."

1.2 The Dynamics of Group Work in SAL

During their interviews, SAL alumni spoke not only about how Chem 110 was affecting them as second-year students. They also reflected at length on how the felt about the course looking back on it six months later. The most salient recollection--which ran like a constant refrain throughout the interviews--was that working in groups played a significant role in their learning processes. Group work was salient for students whether or not they were functional groups. Accordingly, this set of constructs is organized into those associated with functional groups, and those associated with dysfunctional groups.

Information about the proportion of functional and dysfunctional groups is available from the Spring 1995 survey. Seventy-two SAL students responded to the question about whether they had problems in their groups; of these, 61% (44) reported no problems, while 39% (28) reported problems. However, both interview and other survey responses indicate that even those students who reported having problems realized the value of group work, with many mentioning the importance of knowing how to work in groups for today's working environment.

1.2.1. Functional Groups

Most SAL alumni interviewed had been in functional groups, and strongly preferred this learning format to the traditional lecture format. The following quote from an SAL alumna typifies these students' descriptions of their group experiences.

Using 110 as an example, I can look back and see countless hours of sitting in someone's dorm room, either figuring out the problem sets or trying to figure out the problem sets with two, three, four other people sitting around just all throwing out ideas, generally being stumped on one problem for an hour or so and just all throwing out ideas, you know, calling other people up seeing what they think, or with my lab group, sitting in front of the computer and trying to figure out spreadsheets and ways of obtaining the result we want and just all throwing ideas out and seeing what would work, what wouldn't work. I think that was the best way of learning, I found, because you had to - sure, maybe you had the book in front of you, maybe you were paging through trying to find an equation that would work, or a concept, but still, you had to pull this stuff out. Maybe it was kind of obscure and far away and you had to apply it, so I think that was - probably the best way that I can I think [of to] learn.

While elaborating on various facets of their new understanding of group dynamics, they emphasized 1) the relationship between challenging problems, group work, and valued accomplishments in learning, 2) that they developed valuable group skills, 3) that they acquired friends and had fun, and 4) that group dynamics are both complex and productive. These points are presented in the following interview-based constructs.

1.2.1.1 Relationships between Group Work, Challenging Problems, and Deeper Learning

Learning from peers is effective. Many SAL students in functional groups stated that learning course material through group work increased their understanding. They explained that it was because their classmates could explain ideas to them at their own level that they understood more. Students expressed that when other students, rather than the instructor, explained ideas, it increased their understanding of the material. As their peers were at the same level, they felt more comfortable asking them "stupid questions." Students, in turn, learned by explaining to fellow students. Typical SAL responses are below.

> *They [the group] were actually kind of helping me learn what I didn't understand. We just kind of worked together explaining different things, and that actually helped us learn....That group learning actually did help me for that first exam.*
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> ********
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> *When he [the professor] actually had the groups go up to the board...and explain how they did [the homework problem], that actually did help out a lot. To kind of explain what was going on in lecture....When it's actually someone who's in the class, and my age, in the class I kind of listen to them more. For some reason I just kind of respect what they're doing more. Because they're going through the same thing I am. They'll understand more what I'm going through than the TA. The TAs, they had this a long time ago. What they know is way beyond what we know, and sometimes they explain it and it's more difficult to understand.*
>
> ********
>
> *A lot of the times, I know I wouldn't understand something, and someone else would, and they'd be able to explain it to me. Or, I would understand something that they wouldn't, and so I'd be able to explain it to them, and so I was able to understand things a lot better, than just trying to ask the professor one on one, or my TA. I was able to ask a friend, "Okay, I don't get it." And he'd be able to help me, or she, whatever...It was just easier cause it was more of a one on one situation, and it was easier to talk to a friend of mine that go to the professor, and [and say], "I don't understand this."*

Challenging problems force group collaboration. Closely associated with students' perception that they learned more by working in peer groups is their perception that the problems assigned in Chem 110 were so challenging that were forced to work in groups in order to solve them, and that the result of this hard collaborative work was a deeper level of learning. When describing this complex experience, students also tended to communicate that they took great satisfaction in both the process and the resulting learning achievements. The following interview excerpts

make this complex point.

It was a challenge, the whole course, and being in a group just helped you get by. I don't think I would have done it by myself, got through that class by myself.

****

I kind of liked it, because I thought the problems were really tough that we were working with, and there was four of us in our lab group, and we got along really well, and so we were able to collectively work through the problems and get the right answers, so I really liked it.

****

I noticed that there was a couple of times when you know, especially when like people were calling me to get into groups that the problems, I would just look at them and I would be going "Oh my, this is insane." I mean I could swear to the fact that they were set up so that you almost had to work with about three people to figure out what was going on just because they were that difficult.

Group Work Associated with a Repetition that Results in Meaningful Understanding. Many SAL alumni described a special kind of repetition that they experienced in Chem 110. It was not a matter of "drilling in" an algorithm. Rather, it was a type of repetition that enabled them to comprehend the big picture while also understanding the nitty-gritty details. They described a type of repetition that takes place as groups of individuals work through challenging problems. This kind of repetition goes beyond memorization, and leads to making new conceptual linkages between theories and applications. Below are typical SAL quotes that make this point.

Plus with all the group work you were constantly going over the material over and over again. It was really ingrained, so that gave a little bit more confidence. ...Especially with the labs, in the group labs that we had to do, there was a lot of doing the same stuff over and over again and the same calculations over and over again, so that helped in just doing it, constantly doing it. You have to understand it and know it and know it really well.

****

Where I learn, is doing problems and seeing problems done, right in front of me and allowing me to interact too. That's probably the best way that I can learn...I understood what [the professor] was lecturing about, but for me to comprehend it, for me to actually get it in my brain, I had to actually do it myself and solve some problems by myself or with groups or on a piece of paper instead of just staring up at the board.

Deeper Level of Understanding through Valuing Multiple Viewpoints. SAL alumni explained that they came to value multiple viewpoints, the different things you learn from different people. They learned to "pool our knowledge together." These students explained that through peer interaction in groups, they achieved a deeper level of understanding. The students indicated that the problems in Chem 110 encouraged a number of approaches and through the group work the students realized, many for the first time, that different people think about chemistry in different ways. This was important to students for several reasons. Most students' previous chemistry

teachers taught them to use specified procedures to solve certain types of problems and as such, provided little room for the students to develop their own approaches. They valued encountering students who approached chemistry differently from themselves. Below are typical SAL responses.

> *If a group could do it better than I could by myself, then definitely [I prefer working] with the group…If you don't understand something and start off going the wrong way, I mean, totally missing something, if there's something that you might miss conceptually, then you probably want to get together in the group so you don't miss it so that other people who would normally cover that point would still be there, and then another something that they missed somebody else would see or understand.*
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> ********
>
> *When we did group work last year, it wasn't a give-take kind of think, it wasn't like one person gave and one person take, it was let's all pool our knowledge together.*

1.2.1.2 Developed Valuable Group Skills

In functional groups students learned various group skills from each other through their interaction. Through the cooperative setting established in the groups, the students contributed their differing skills and knowledge. Most students saw group work as "mirroring" real life. Many learned by teaching others or having others teach them, while a few learned stress management skills and developed patience.

Learning environment that mirrors real life. Most students valued and saw SAL as helping them develop real-life skills. Presented below are typical responses.

> *I loved it. I loved working in groups. Because unfortunately life is a bunch of different people and you have to work with a bunch of people. And I think too many people down here are introverted. Everyone does everything by themselves. It was great having to do stuff with different people and then switching groups. Life is that way. It's good that we learned how to do that.*
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> ********
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> *I suppose if you look at real life situations - I think you should probably have a learning environment that should try to mirror real life situations - the group work is probably going to be a lot more important than sitting by yourself in your room and cramming for an exam, which I have to do tonight for organic chemistry.*

Importance of Integrity and Responsibility (Preparation). Students who had functional groups expressed a strong sense of integrity and responsibility toward the group. Many students stressed the importance of being prepared before getting together with their group. They were worried about being perceived as a slacker or feared holding the group back. Students in functional groups indicated the group goal was that everybody should learn. Below is a typical quotation that makes this point.

For some of the chemistry labs, groups are a really good way to learn because a lot of the labs are very detailed, and there's a lot of things to be doing, so in that perspective, having a group is really nice, but in some other classes, I can think of my engineering class, if we had assigned groups, I think there would be a problem of people slacking off. Just like, "Oh, do you have #2. Can I copy that?" type of thing, and so I don't think groups there is a really good idea. Cause in a group you are kind of forced to share your answers with a group. But when my friends and I get together, you know, if I know he didn't do it, I'm like "No, I'm not going to give it to you. Do it on your own. If you get stuck, or something, I'll help you, but if you haven't even tried it, then..."

Stress Management. A few students explained that a valuable skill learned was stress management. These students experienced considerable tension and yet were able to resolve their conflicts in a mature fashion. Students explained that one strategy they employed was taking a break when they simply were unable to work any longer on their project. They didn't simply walk away from each other, but continued to be able to socialize together after an intensive group session. Having a group of others to work with kept many of the students from getting overly frustrated when they were faced with difficult problems. Illustrated below is a typical quote.

Any problems that we had were just if we all started getting kind of stressed out and just really didn't want to be there. Whenever that happened we just ditched out of lab or whatever...We would just all go do something like head down to Pizza Hut or something like that. Just go and blow off chemistry for a night and come back some other time....Everyone I think adapted a little bit. Some people just changed to work as a group.

Patience. Another way a few SAL students learned to work better in groups was by developing patience with others. In a functional group, part of developing this patience was learning to gear themselves to the level of the group with whom they were working. Students reported that some group members needed more time to learn and it was necessary to be patient. Below is a typical SAL response.

I [am] finding that when groups are required or encouraged to do something, I can work with them a lot better than I could have if I had never taken 110. I've learned a lot more patience working with these people, dealing with ideas being thrown around. And also kind of working to their level a little more rather than expecting them to come to mine. If they're going to work fast, I just make sure that I'm a little better prepared for lab than I would have ordinarily have been.

1.2.1.3 Fun and Friends

All of the SAL students interviewed described how group work fostered a supportive environment which they found useful and comforting. Students also stressed the *fun* of working together and how they welcomed the opportunity to make friends. In a functional group, a sense of camaraderie, of belonging, of meaningfulness were related. It enabled students to develop their own learning community. In addition, group work provided motivation thus making learning more enjoyable. The following are typical quotes relating to how the groups provided support and friendship.

> *For one, you get a concentration of friends, that's a better way of meeting people, because if you just meet someone in one lecture, and then you meet that person again like 10 lectures later, they're gonna be, "I don't care." They're not going to remember that you spoke to him, but when you're in a group, you would associate that person again with that group, and you remember everyone who was in the group.*
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> ********
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> *People in my lab group, I got to be really good friends with just because you spend so much time with them.*
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> ********
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> *I made really good friends in that class, the group that I had was really fun...We had a crazy group, so it was fun.*
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> ********
>
> *Sometimes it made, depending on the group that I was with, it made it more enjoyable to work, and it was a lot easier to do things and to get motivated to do things because you can also have a good time with other people instead of being by yourself doing the work.*

1.2.1.4 Group Dynamics Are Both Complex and Productive

Current literature on group process (Scholtes 1994, p 6-4) states that groups progress over time through four stages: forming, storming, norming and performing. These four stages explain how groups of individuals come together to form a group that functions as a "team." A few students described group processes that suggest they were in a "storming" stage characterized by argument and conflict. "Storming" is considered typical, as groups evolve to a new level or development in understanding. Students reported the process of resolving conflict as a valued learning experience. Below are typical SAL quotes.

> *We had problem sets and sometimes we would do those together and turn in one set for all of us. I liked it. Sometimes it felt like I could have done it faster if it was just one person at a time because sometimes there's conflicting ideas and it's just a waste of time, but I think overall it was helpful.*
>
> ********
>
> *Sometimes we didn't get along. I think in the end we worked it out because we would do things different ways, but I don't know. It all worked out for us. Maybe we were just*

lucky. I still work with a couple of my lab partners when I do my homework, from last semester even...I don't know, we'd all just basically get pissed because somebody wanted to do it one way and somebody would want to do it another and we'd probably just be mad about it for a while and somebody would give in and then we'd do it one way.

1.2.2 Constructs Associated with Dysfunctional Groups

SAL alumni in dysfunctional groups conveyed that they failed to develop the skills necessary to allow productive group results. They reported three main problems: the slackers, the controller, and an uneven level of knowledge. The slacker is an individual who lets others do his/her work. The controller is the student who takes over the group without consensus. The third problem entailed some students having more or less chemistry knowledge than the other students.

Many SAL students described four types of factors associated with unproductive groups. A few SAL students reported that certain individuals ("controllers") took over the group, while others ("slackers") contributed nothing. The students who contributed nothing led their group mates to feel "used." A few students said that "impatience" by them or by others sometimes prevented their groups from working cooperatively. This was more likely to happen when students have notably different levels of chemistry knowledge. Another problem noted was when students got correct answers from the group without understanding the concepts. A fourth factor was students who openly resisted working in groups. Because of the primary emphasis on group work in SAL, groups where these factors were common tended not to establish productive group dynamics and led to students having overall negative attitudes and experience in class.

1.2.2.1 Controllers/Slackers

A few SAL students reported that certain students did all the work for the group or took charge of the group. Sometimes an individual dominated against the expressed will of the others, while other times one student became dominant because the other members of the group did not contribute and thus forced him/her into this role. Students said that a slacker is a student who comes unprepared for class or does not show up at lab. The following quotes describe "controller/slacker" dynamics.

In our labs towards the end there my friend, he ended up taking charge of the entire lab most of the time. We ended up just doing little small work and he was doing most of the work...[My friend] took control of most of [the lab] and the other helped out a little bit. One kind of didn't show up at lab too often, and then I just kind of did a little grunt work.

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...so [one person in my group] ended up becoming a friend of mine and using my lab, so we ended up staying together for every single lab. And he was the one who did the majority of the work. Because he was just that kind of person. He just likes taking control and doing a lot of work.

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So [two of the students in the group] would do all the calculations all the time, and [another student] and I would never do them, so we never really knew what equations they were using or how they were getting them or anything like that, even though we knew what the concept was behind it.

1.2.2.2 An Ethic of Impatience

Students who had functional groups reported that everyone worked together to help everyone understand, even when not everyone was well-matched with respect to chemical knowledge. By contrast, some students who had dysfunctional groups reported a group ethic characterized by the faster students acting impatiently. Rather than working together, these students' goals were to get the answers and leave.

What happens to me, especially in a group, is that the group will get impatient with you. Let's say there are four people. There's two that really know what they're doing, one that's kind of in the middle, and - well let's say that there are two of us in the middle and two that are doing really good. Well, let's say this is about three hours worth of problems. OK, the people that are going to get done quickly, they'll get done in three hours and we'll be done with say, two thirds of the problems and they'll stay for about ten more minutes telling us what we haven't figured out yet. And finally they'll just get disgusted and leave because they get tired of telling us how to do something and then the two of us kind of sit there going "Well, thanks a lot." People didn't really walk out on you, but in a larger group they just tend to either peel off or they kind of form their own little group and do their thing. But over enough time it tends - a group will tend to break up like that.

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And I would walk in and I've read the chapter and had a pretty good idea of what's going on there. And then the entire group would pretty much go through the problem sets, but then if there was more than about three of us, then you start seeing little groups of three break off. And part of them would be done in an hour. And some of us would be sitting for three hours and some would be sitting for six. You lose the whole interaction thing just because some groups work faster than others.

1.2.2.3 Spoon-fed Answers and Loss of Confidence

Students whose faster colleagues treated them with impatience explained that they often ended up accepting from a group answers that they did not understand. They indicated that when they were uncomfortable and intimidated by the abilities of others, they were more apt to absorb what was going on passively rather than actively participate in the problem solving process. Finding themselves writing down spoon-fed answers, they knew they were not only failing to get a solid foundation of chemistry knowledge, but also losing self confidence. These students "got by" or even got a good grade, but they had a negative experience in the class. Illustrated below are typical responses.

And we got along really well. We had some really good times. Overall, I never understood anything because I never had to figure it out by myself. There was always three people other than me there, and even though we could talk about it, once someone tells you something, you haven't gone through the process of how to figure it out. That didn't help me very much!

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One "con" I found about the whole thing was at times, like, something - it kind of decreases your confidence if you don't know the stuff. Because if you know the stuff then you can put in your contribution to the group, but if you don't know the stuff you're relying all the time on your group, and then eventually you may fall back. Although you're in the group, you're part of them in the work, but where the understanding is concerned, if you don't understand it and the group understands it and goes ahead... ... If you're doing work individually, it's all your work, so you know whether you're right or you're wrong or how good you are at it. When you're in the group, then it all depends on how much you kind of contribute to it. I guess if you're starting in a group there should be equal contribution, but your confidence as an individual changes.

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And you ask the really fast group a question and they're like, "Oh, well, it's you know x, y, z. Isn't that easy?" And I'm saying "No. I need that explained." And they would just kind of go "Wow. You need help."...That's the only thing though that I can see that - under the wrong conditions a group can really mess you up because you'll end up turning in something you don't understand. Psychologically you feel like you really got blown away by the rest of the group just because they finished it lickety split.

1.2.2.4 Resistors

As in reported in *Chem 110 Formative Feedback Report #3*, a few SAL students simply didn't like the concept of collaborative work and admitted *resisting* this approach. These students preferred to work alone, and resisted the required group activities. A subset of these students, however, expressed regret during their sophomore interview at not participating as illustrated below.

Most of the time I just attempted to do something on my own. If I couldn't figure it out, then I just stopped. Well actually towards the end of the year I studied a little bit with my friend, but not a lot. Just when I was really puzzled about what to do. Actually I hadn't had any collaborative learning at all...I just really don't like working in groups. I just like being independent working on my own.... I just feel more comfortable like, working on my own, just trying to work in the book and learning on my own.

For Chem 110 actually, I never studied at all with anybody and actually I didn't do so well on all the exams. So I kind of figure if I actually would have worked together with these guys on that too, that probably could have helped me out more. Just because it brings out,

when you talk things over it keeps it fresh in your mind and it helps you to remember it all. Like I didn't do that in Chem 110, so it just totally dropped me down...It's kind of like I didn't actually do a group study, and I fell behind in there, and actually never really felt the need to catch up. And now that I look back on it, I think that if I actually would have gotten together in the groups and actually studied with my friends and did the homework with them and just talked it through with them that I actually would have learned a whole lot better. [Group work] helps you remember the stuff a lot better.

1.3 Well-integrated Course Components

For many students the course material is a vehicle to problem solving and creative thinking. Developing problem solving skills were the most important for students. They learned through the problem solving assignments as noted by the SAL students below.

I thought that lab was really well coordinated with what we learned in lecture. That was really important to me.... I think whatever we learned - and maybe a lab covered stuff a week back, but, even stuff that was done in lecture a week back is a little bit fresh in your memory. Just because - it was never a week back because we had two labs a week and four hours each, and they were really extensive, so we had a lot of lab work. It always - even though there were steps, like, do this, do this, do this, do this, but it always got back to understanding stuff... Just, disregarding like the first two experiments, every one of them kind of, somehow, linked back to what we did in lecture. The first was measuring and weighing stuff, so we can disregard that...I think it was really well set and that the lab really coordinated with what we did and that helped you understand better.

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Just more explaining to myself, writing little notes to myself, clarifying it on paper, not just clarifying it in my head, and thinking about it a couple days later.

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Some of the big projects and some of the problems you had to visualize how you got from A to Z through a bunch of intermediates. In that sense it does kind of, because you can open your mind to more things and how you get from here to there, but direct - like, with the stuff that we learned, acid, base, and all that kind of stuff, that's not helping very much right now. But seeing how you get from here to there is kind of - I can't put my finger on it.

I think a problem in one class, is it similar to a problem in another class? I can see that. In my engineering class we just did heats of reaction, heats of formation, and we did that in chemistry, did that in physics.... A lot of the concepts from my engineering class came from chemistry classes that I had...I mean just a lot of all of the general things of chemistry I'm using in my engineering class.

Lecture - this is the first one where I really had to keep track of lecture by lecture. I would get lost and blown away. It was a lot like my math course I had last year too, but this was

another that kind of reinforced that if you weren't keeping up with what was going on, you were going to get lost. It wasn't just like you were going over ten different subjects over the semester where you could just say "OK, now we're just going to move on to something completely different. If you didn't get the last thing, that's OK." That way it was really helpful that way.

1.4 Open-ended Group Labs

Many SAL students stressed that, compared to canned labs, the open-ended group labs forced them to draw upon their understanding of theories and make deeper connections. Below are typical SAL quotes.

The group labs really forced you to understand the material and understand what you were doing instead of just following directions. A lot of times you just read out of your lab manual and follow the directions. You don't really think about what's going on and why you're doing this. So the group labs and the way they were set up, being really open-ended, in that there wasn't really any [particular] answer you were supposed to get, that kind of forced you to use what you were learning in lecture and forced you to move it into the lab, whereas in a lot of other lab classes that I have had it's just, "Go do the lab. Hand it in. And maybe think about it a little bit." [It is more about] getting the lab done.

****

...the labs - we did kind of a combination of both in ours. About the first half of the year was mostly, "Can you as an individual get what you're supposed to?" "Can you do the techniques right? "Can you get the right answers?" And then after that they said, "OK, you seem to know what you're doing." Or, they assumed you did. And then you moved on to using these things in a group. And that I think was nice because I was not just taking the whole semester doing the individual thing where they say "OK, now today we're going to find out how much of this is in this chemical." Or "today we're going to do this process this way and we're going to do this."

2. The Responsive Lecturing (RL) Course Culture

2.1. Lasting Effects of Responsive Lecturing

What lasting effects of Chem 110 did RL interviewees perceive as persisting for them six months after they completed the course? Listed below are key constructs about the lasting effects of RL. Chem 110.

- voluntary group work
- content of course material
- lasting friendships

One student mentioned that he did change careers as a result of his Chem110 experience.

2.1.1 Voluntary Group Work.

Many RL students reported that they continued working with other students in groups or in pairs. Below are typical RL quotes.

> *[In Organic Chemistry, I work with] at least about two study groups a week pretty much. A lot of group work that we do together. A lot of studying to do together. Physics too.*

> *Every Sunday night I get together with this guy to go over physics problems that are due the next day. I am sure if I did them totally on my own I probably wouldn't understand as many.*

2.1.2 Course Content Useful

A few RL students reported that they continued to use information that they had learned in Chem 110. Below are typical RL quotes.

> *I applied a lot of those concepts and theories that I learned in Chem 110. I think it's actually the most useful class I have had so far in college.*

2.1.3 A Few Lasting Friendships

A few RL students reported that they made good friends in Chem 110. Below is a typical RL student remark stating this outcome.

> *I guess it kind of affected my life, I have a lot of good friends from Chem 110. (laughs) I mean I spent a lot of time with some of them.*

2.2 Learning Experiences Associated with the RL Course

Chem 110 RL alumni felt that the class had taught them how to study, that they had made connections with the course material, changed their career direction, and repetition with variety.

2.2.1 Students make connections

Many RL students reported making connections with the class material. They were beginning to understand the concepts. Illustrated below are typical RL quotes.

> *I was use to...where all you have to do is turn in a great lab report. [The TA] said, " I am not so concerned that your lab report looks cool as long as I can read it, but I want to know what you got for results and how you got there." Then all of a sudden it becomes a lot more important that you are doing things correctly, that you are taking time to look at it again and in that way I think you also learn the concepts better too, because you have to come back and say "Wait, was this how it was suppose to be done? Yes, and I can prove it because I got the results that I was supposed to on the paper and it agrees with the theory."*
>
> ********
>
> *And you'll go "Oh yeah, I learned that in Chem 110, or this goes back to chem 109." I think it's always there. If you learned your subject and you learned it well enough than it's still kind of sitting in the back of your head. I don't know. You'll be looking at this or you'll go "Oh yeah, I remembered something like that." or "Oh yeah." I've made connections. It's just sort of haphazard. You'll look at something at it will come to you.*

2.2.2 Learned how to study.

A few RL students reported that Chem110 taught them how to study. One female student was motivated by high the caliber of students. Illustrated below by the following quote.

> *But for some reason that class just, maybe it was [the professor], maybe it was the people in there, the caliber, just made me want to do really well. And so that class really taught me how to study. (female)*

2.2.3 Repetition an important feature of the learning experience

For a few RL students repetition or practice was important to learning. Repetition stimulates understanding that goes beyond memorization allowing linking, understanding, and application of concepts. Illustrated below is a typical quote.

> *Probably just the problem solving, just the practice. You get a lot of practice at just doing, trying to figure things out and looking for an answer that you might not expect. It was kind of nice for that class. Everything wasn't written out for you. (female)*

This theme of repetition by RL students is reflected in by the open-ended survey data. For RL students repetition included difficult problem-solving calculations (28%), homework (13%) and labs (11%).

2.2.4 Lab and Lecture Should Be More Connected

Many students felt that lab and lecture should be more connected in order that they could make connections with the material being taught, while a few found the labs useful as is and appreciated the effort by the TA/professor for them to understand the material. As reported in FF#3, many RL students expressed the concern that there should be a greater connection between lab and lecture. Without lab and lecture being connected, students failed to see the relationship between theory and application. Below is a typical RL quote.

> *Labs for me are alright, but I never thought that much of them. But in this class, I thought the lab was so much more important. Not only interesting, but more meaningful than the lectures. [The RL Professor], he's a really good professor. Really personable and everything. I didn't get what he was getting at in lecture. I didn't understand the whole scope of analytical chemistry and what the prof was trying to put across to us, but I didn't feel that it related or it really was that important.*

Lab and lecture needing to be more connected for RL students is reflected in the open-ended survey data. Twenty-four percent of the RL students mentioned they failed to make connections between the lab and the lecture in class. (In contrast, only 4% of the SAL alumni mentioned this.)

2.2.5 Emphasis on Accuracy Led to Strong Lab Skills

Many students appreciated the emphasis on accuracy in labs. A few reported that they acquired strong lab skills that could be used in future classes. One student even said that this helped him learn the material better. Below are typical RL quotes.

> *I was used to the kind of things he was talking about where it's just like all you have to do is turn in a great lab report. He said "I'm not so concerned about that your lab report looks cools as long as I can read it, but I want to know what you got for results and know how you got there." And then all of a sudden it becomes a lot more important that you're doing things correctly, that you're taking time to look at it again and in that way I think you also learn the concepts better too because you have to come back and say "Wait, was this how it was supposed to be done? Yes, and I can prove it because I got the results that I was supposed to on the paper and it agrees with the theory."*
>
> ********
>
> *He brought up a really good thing that I forgot about. Which was that lab was really useful. It was really demanding. In fact I liked part of the fact that it was all on your own responsibility. If you didn't get a good answer it's because you messed up somewhere.*

And a lot of it was just perfecting how you did something and making sure that you were doing it right. And sort of working it all out on your own. All that responsibility was on you and I really liked that because in high school there was a lot people and again in chem 109, it didn't even matter what answers you got as long you hand in you know, really beautiful lab report and told you know, where the arrows were from. But in chem 110 it was really important to get decent data. And so - I put a lot of effort into it. And you would see the result. Like the more work you put into it and the more precision you tried to get, and the more you really work at it you can see that it would pay off. I could see myself using that later.

2.2.6 Degree of Connection with Professor Varied

Connection with the professor was very important to many RL students. When there was connection, the class was a positive experience, without that connection the class was less than fulfilling. Below are typical RL quotes.

I really loved the professor. I had a lot of interaction with him. I would be after class almost everyday just asking him questions. Maybe that just sort of made me feel a lot more comfortable talking to other professors about - I just had such a really good experience with it. I came out of there going "Gosh, I really love this chem department."

For a few students a direct, personal connection with the professor wasn't necessary for it to be a fulfilling experience.

[The RL professor] is the most brilliant person I've met. (laughs) He sort of created his own little way of teaching analytical chemistry which I think blew the minds off of all of us. It's really useful to have everything home on my computer. And if I ever need it again, look at my notes and just open my computer and "Gosh, a live log plot."

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I probably get more out of the problems that I do at home or any of the reading in the text that I do. I think it kind of depends on the lecture. [The professor] was a good lecturer. He really kept you into it. I don't think I ever fell asleep in that class.

For a few students lack of personal connection with the professor was important.

...he was more--kind of like--the figurehead professor in the front of the room and we were just watching him and he was putting on a show for himself. But, that's not true, either though, 'cause he was always asking us questions and always making sure we understood, too. He just didn't want to get to know us, as a person. (female)

2.2.7 Group Issues

2.2.7.1 Preference for Voluntary Collaboration

Most RL students preferred working alone or to work with a group they selected. Many RL students have had negative feelings about group work. These students reported that they previously worked in a group with a slacker or a controller. Below are typical RL quotes.

> *I think the one thing that happens when you try to force collaborative learning on people, is it always seems like somebody's always doing more of the work than somebody else. Somebody takes charge and you know, maybe that's good and maybe that's not. Somebody's generally along for the ride.*
>
> ********
>
> *But I was actually quite happy that I wasn't forced to be in groups. That it was my own personal choice. And everybody was really great about it. So you could always find help if you needed it. But, if you didn't that was fine too.*
>
> ********
>
> *I specifically got into [the RL professor's] course because I knew it didn't have any collaborative learning. I really like that. I prefer the sort of collaborative learning where you would go out and you would get the people that you - and you can make your own schedule around it, you aren't forced into it. (female)*
>
> ********
>
> *I still don't particularly like collaborative learning. I would always end up doing the most work. Just really having to do any - do everything. It never gave me anything. I would always end up kind of doing it all and getting really mad about it. So I really had very bad experiences with collaborative learning in high school. (female)*

Group interaction was valued by many RL students because they were free to work with whomever they wanted and if there was a problem they could leave the group freely. As mentioned in FF#3 report, students valued voluntary collaboration, but resisted assigned group work. Also as mentioned in FF#3 report, many of the students had formed groups. They said that the support their groups provided them was important in learning and understanding chemistry. These students also expressed a higher degree of satisfaction with the course than students who had not formed groups. Below are typical RL quotes.

> *The benefits are that when you don't know something you can find out the answer. I don't know if it's really much of a problem just because it's not a required thing. You don't have to work with someone, so like if there's a personal conflict or something then you don't have to work with them so there's not really much of a problem.*
>
> ********
>
> *When you're with your friends, you pick them out yourself, so you're not really going to have much of a conflict with your friends and if you do you can usually laugh at it or just go on with and not worry about it.*

****

The really good stuff about working in groups is that you get a lot of people together and they have a lot of different ideas. And you can work things out some times a lot easier. But I myself personally have found that there is only so much group work that I can handle. I do a lot of my best work when I'm on my own. And I have peace and quiet and I can just sit pencil and paper and just work it out. It's kind of a combination of the two that works the best for me. It also depends on the subject. Organic this year takes a lot more group work than I really thought. And so it just sort of depends on what subject it is and how much I feel I need help. (female)

****

When I know something real well I'll work in a group so I can help somebody else out, or when I don't know something or when I'm close to knowing something, I can when I they associate something I can usually figure it out from what they've said or something that they can figure out, kind of making that next step.

Voluntary collaboration by RL students is verified in the open-ended survey data. Four percent of the RL students mentioned that they collaborated voluntarily with other students. (SAL students were required to work in groups).

2.2.7.2 Group Work Valued by a Few

As expressed by their SAL counterparts, many students stated that learning the material through group work increased their understanding because their classmates could explain ideas to them at their own level. These students expressed that when other students, rather than the instructor, explained ideas, it increased their understanding of the material. Their peers were at the same level and they felt more comfortable asking "stupid questions". Students also learned by explaining to fellow students. Below are typical RL quotes.

I did a lot of cooperative learning, just with people in my dorm, and we'd like work on the homework together. As far as what effects it had on my, I just got my homework done and a few of the problems, when I had problems, I could get help with them because there were about five or six people I knew in my class doing the same stuff, so usually at least one of them knew what they were doing with some of these problems so I could always get help.

****

I'll be sitting with somebody and I'll be "Let me explain this to you, just so I know that I know it." That's nice. Sometimes it is kind of a problem, because I know a lot of people - every Sunday night I get together with this guy to go over physics problems that are due the next day. I'm sure if I did them totally on my own I probably wouldn't understand as many.

"Brainstorming" valued. RL students mentioned that brainstorming was meaningful. Below are typical RL responses.

> *When we are required to come up with many new, creative ideas, bouncing ideas off each other would facilitate thinking and creativity.*
>
> *Students should first brainstorm and think for themselves about a certain topic and then discuss it in a group.*

APPENDIX B

Content Analysis of Open-Ended Survey Questions

Table B.1
Summary of Open-ended Survey Constructs
Spring 1995 Chemistry 110 Alumni

Categories	SAL N	RL N	SAL %	RL %
1. Looking back on your Spring 1995 semester, please comment on your experiences in Chem 110 overall. (Question 18.)				
1.1 Learning Accomplishment Valued				
1.1.1 Challenging but worth it	28	13	37%	28%
1.1.2 Learned Lots	26	5	34%	11%
1.2 Positive Effect of Professor	19	4	25%	9%
1.3 Group Dynamics				
1.3.1 Group Work Valued	18	2	24%	4%
1.3.1.1 Understand Concepts Better				
1.3.1.2 Friends				
1.3.1.3 Voluntary Collaboration				
1.3.1.4 Helps in sophomore classes				
1.3.2 Group Work Dysfunctional	4	0	4%	0%
1.4 Connections				
1.4.1 Positive Connections	7	0	9%	0%
1.4.1.1 Real World Connections				
1.4.1.2 Connections with current classes				
1.4.2 Negative Connections	3	11	4%	24%
1.4.2.1 Lack of Connection between Lecture and Lab				

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Categories	SAL N	RL N	SAL %	RL %
1.4.2.2 Lacked "Real World" Connections				
1.4.2.3 Material "acontextual"				
1.4.2.4 Lack of Connections with Concepts				
1.5 Confidence				
1.5.1 Positive Confidence	5	0	7%	0%
1.5.2 Negative Confidence	3	2	3%	6%
1.6 Chem 110 Experiences Overall				
1.6.1 Positive Overall	24	5	32%	11%
1.6.2 Negative Overall	7	2	9%	4%
2. Did your Chem 110 experience influence you to work in groups during this semester (Fall 1995)? (Question 15.)	40	13	53%	28%
2.1 More Willing to Work with Others	21	5	28%	9%
2.2 Chem 110 classmates are in current work groups	8	2	11%	4%
2.3 Understand More	12	3	16%	7%
2.4 Working in Groups Helped Me Meet Others	7	0	9%	0%
2.5 Less Willing to Work in Groups	5	0	7%	0%
3. What types of course work, if any, are better accomplished by student groups? (Question 16.)				
3.1 Labs	36	5	47%	11%
3.2 Difficult Problem Solving	26	13	34%	28%
3.3 Brainstorming	7	8	9%	17%
3.4 Projects	10	5	13%	11%
3.5 Homework	5	6	7%	13%

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Survey Administration

Surveys were administered to all (180) Spring 1995 Chem 110 alumni seven months after they completed their Chem 110 course, and resulted in a 68% return rate.[1] The open-ended questions analyzed here appear as questions 14, 15 and 18. Table 1 shows the number of surveys sent to and returned by SAL and RL students.

TABLE B.2

Survey respondents by lecture and sex.

	SAL			RL	
	Alumni	Respondents		Alumni	Respondents
Male	60	42 (70%)		49	28 (57%)
Female	44	34 (77%)		27	18 (66%)
Total	104	76 (73%)		76	46 (62%)

Analysis of "Mentions": A Content Analysis Approach

A majority of the student respondents provided substantial responses to the open-ended survey questions. We used an inductive coding process to analyze these responses. Reading through all the responses, we noted patterns and "named" each of these with a phrase to which we assigned a code for sorting purposes. For example, the coded phrases resulting from our analysis of responses to Question 18, "Comment on your experiences in Chem 110," are:

- Class is challenging, but worth it
- Learned lots
- Positive effect of professor
- Group Work Valued
- Group Work Dysfunctional
- Positive Connections
- Negative Connections
- Positive Confidence
- Negative Confidence
- Chem 110 was a positive experience

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[1]We distributed the survey to all 180 Chem 110 alumni and received a 50% return by late December. In early January, a second mailing including a duplicate of the survey and a letter promising a $5.00 pizza certificate for a returned survey was sent to the homes of non-responders. This mailing resulted in a total response rate of 68%. (Pizza certificates and a "thank you" letter also were sent to the 50% who responded without a "bribe.")

•Chem 110 was a negative experience
•(A very small number of students mentioned TA's and the textbook.)

Simple responses were coded with just one code. For example, we assigned the response, "Chem 110 is the best and most rewarding class I have had at this university," with the code for "Chem 110 was a positive experience."

We gave several codes to more complex responses. For example, to the response that appears below we assigned the codes for the six phrases appearing after the response.

> *Chemistry 110 was my hardest class by far. At times the work seemed overwhelming, but I got it done and learned so much. Without 110 this semester would have been so much more difficult because I learned good problem solving techniques last year. Group work this year was beneficial because of my experience last year. I had confidence in myself going into organic chemistry-that I would be able to do well, the confidence has really helped too. Chem 110 by far is the most challenging and most rewarding course I have ever taken. It teaches good life lessons of valuing hard work and cooperating with others.*

We then assigned the codes to each response. The six codes and phrases assigned to this response was 1) class was challenging, but worth it, 2) learned lots, 3) group work valued, 4) positive confidence, 5) helps in subsequent course, and 6) Chem 110 was a positive experience.

This coding process allows us to translate very complex open-ended responses into numbers of students who voluntarily "mentioned" particular aspects of the course. This method has the disadvantage of understating the complexity of many students' analysis of their learning experiences. This disadvantage is particularly notable for the SAL students, whose responses tended to be longer and more textured. However, this process has the advantage of enabling comparison by section across standardized "mentions."

It is important to interpret the information presented below as a content analysis of qualitative and quantitative analysis techniques. The data are "open-ended" in that categories of responses were not pre-formulated by the researchers, and thus any patterns that emerge are genuinely those experienced by the students. Yet, because there is a sufficiently large number of responses that present clear patterns that we can count and compare by codes assigned on a post-hoc basis, numeric analysis is useful. It is useful, however, only if the numbers are interpreted for what they are: "mentions" of emergent themes developed on a post hoc basis. Thus, "whereas 37% of the respondents" may be a relatively insignificant percentage when referring to responses to a multiple choice item, "37% of the respondents" is a significant percentage when referring to "mentions" of a pattern that detected in open-ended material.

1. Analysis of Question About Chem 110 Overall

"Comment on your experiences overall in Chemistry 110" *(Question 18)*
(N=118; 4 survey respondents left this item blank.)

Question 18 was designed to be a completely student generated open-ended question. The purpose was to learn what the students had to say about their Chem 110 experience without any prompting from the survey or the researchers.

1.1 Learning Accomplishments Valued

1.1.1 Challenging, but worth it: Number of mentions = 41

Forty-one students were coded as articulating the point that Chem 110 was a challenging, but ultimately rewarding class. This number included 37% of the SAL respondents (28), and 28% of the RL respondents (13). Typical of the 28 SAL student responses are the following quotes:

Chemistry 110 was my hardest class by far. At times the work seemed overwhelming, but I got it done and learned so much. Without 110 this semester would have been so much more difficult because I learned good problem solving techniques last year. Group work this year was beneficial because of my experience last year. I had confidence in myself going into organic chemistry-that I would be able to do well, the confidence has really helped too. Chem 110 by far is the most challenging and most rewarding course I have ever taken. It teaches good life lessons of valuing hard work and cooperating with others.

Midway through the semester I hated the class, because it was very hard. This was the first time I was personally held responsible for my own learning!...I feel much more in control of my education and feel I can get a lot more out of any class because I am in charge of how much I learn. It is really frustrating when professors don't expect you to or help you, understand concepts at a deeper knowledge than an introduction.

Chem 110 was a very hard course that took a lot of time. It was a very intellectual course that was challenging, yet rewarding.

I found the course to be challenging, but at the same time rewarding. I loved the group work. The rewards of it included: new friends, sharing of information and accomplishment of tasks. The labs taught me new approaches to problems and not to give up.

Not only was a smaller proportion of the RL student responses coded as "challenging but rewarding," but the comments so coded generally were less enthusiastic. Typical of the 13 RL student responses are the following quotes:

It was a demanding and rewarding experience. I do not regret taking the 109-110 sequence at all. Looking at a few topics in great depth is the best way to really learn and know the curriculum.

Chemistry 110 was a very interesting experience. It was also very time consuming, making it affect other course work I had.

I found the class to be challenging, but fun. There are great rewards in completing the course. I find it interesting on how I often walk down the street and wonder what materials does a certain object consist of.

1.1.2 Learned Lots: Number of mentions = 31.

Thirty-one students were coded as articulating the point that they "learned lots" in Chem 110. This number includes 34% of the SAL respondents (26), and 11% of the RL respondents (5). Closely linked to the "challenging, but worth it" code is the "learned lots" code; comments that noted that the course was challenging, but worth it <u>because</u> the student learned a great deal, were given both of these codes. Typical of the 26 SAL student responses are the following quotes.

Looking back, I realize that I learned more then I had thought at the time. Even though the percentage of the material I retained (or fully grasped) was a lot lower than in other classes, I realize now that there was <u>so</u> much to know that even that low percentage probably translated into more learned material than in other classes.

The experience in Chem 110 is great. I can feel that I am learning a lot and the lectures are the ones that I enjoy[ed] most ever since I came to UW-Madison.

I feel that I learned more material in Chem 110 then I ever learned in any other class. I also feel that I put more time and effort into Chem 110 then I put into any other class I have taken. I feel that the time and effort paid off greatly, however...although Chem 110 was not my favorite class, it taught me much more than just chemistry.

Typical of the 5 RL student responses is the following quote.

I learned a lot from lab and homework. It required the most time and work of the classes I have taken so far.

1.2. Positive Effect of Professor: Number of mentions = 23

Twenty-three students were coded as articulating the point that the Chem 110 professor was a positive aspect of the class. This number included 25% of the SAL respondents (19) and 9% of the RL respondents (4). Typical of the 19 SAL student responses are the following quotes.

Prof. Wright was excellent. He was extremely enthusiastic and infinitely smart. I believe the course was enjoyable and worthwhile because of Prof. Wright entirely.

I thought Prof. Wright was excellent because he never straight out told us how to do something, but made us reason out on our own.

My experiences in Chem 110 are only positive. Prof. Wright was wonderful and used his teaching style well. He demanded understanding of concepts and did his best to teach them.

Typical of the 4 RL student responses is the following quote.

I greatly enjoyed Chemistry 110. I found Prof. Woods to be simultaneously a brilliant chemist and a wonderful teacher. He had enormous patience and a constant willingness to explain which helped me numerous times. The subject matter itself was very interesting and I always enjoyed lecture. Lab was also great fun.

1.3 Group Dynamics:

The theme of groups could be broken up into 2 main areas; functional groups (positive) and dysfunctional (negative) groups.

1.3.1 Group Work Valued: Number of mentions = 20

Twenty students were coded as articulating the point that group work was positive. This number includes 24% of the SAL respondents (18) and 4% of the RL respondents (2). The 18 SAL comments about positive or functional group work are divided into three main categories: 1) Group work helps students understand concepts better, especially since the homework was very challenging and time-consuming. 2) Group work has the added bonus of social bonding. Students were delighted in making good friends in this class, and 3) group work in Chem 110 is being sustained and helping students in sophomore year courses. Typical of the 18 SAL student responses are the following quotes.

1.3.1.1 Understand Concepts Better. Only SAL students mentioned that the structure of the class, the cooperative learning, helped them to understand concepts better.

The class was rigorous and group work helped me to understand and learn from the labs. The take home exams were often rather difficult and tremendously time-consuming and frustrating. The group focus was the only thing that helped us make it through. In general, I learned to study several concepts in great detail and thoroughly -- I felt pushed to my limits often and it was then that being in groups made the experience bearable and even enjoyable --keep this setup in the future.

Thanks to the structure of my class, I felt I came to understand the concepts much more thoroughly than I otherwise would have.

I learned to study several concepts in great detail and thoroughly--I felt pushed to my limits often.

1.3.1.2 Friends. Students mentioned that they made friends in groups and kept these friends. They see them in classes as sophomores, work together in groups, and also socially. This feeling of belonging allowed students to feel comfortable with themselves and others. (Only SAL students mentioned that social aspect of Chem 110.)

It was a lot of fun. I learned a lot and there was a sort of camaraderie developed between the students of the class. We will be colleagues through our college experience and, maybe, longer. These relationships will be an integral part of our continuing education. We know we are not alone and will seek each other out in adversity....like a tough organic exam.

I really enjoyed the group work and made some lasting friendships.

Chem 110 united the students. I see classmates now in other courses, we say hello & are really friends. The <u>best</u> part of this course is the friends you make!

1.3.1.3 Voluntary Collaboration. The 2 RL comments coded as "functional work group" focused on voluntary collaboration. Although they were not required or encouraged to, some RL students participated in group work. As one RL respondent put it,

I studied a lot with a group of 4 people and I think they really pushed me to learn the material. I think overall the class was pretty fair. At the time I thought it was hard, but looking back it was a pretty fair preparation for recent classes.

1.3.1.4 Helps in sophomore courses. A few students mentioned that what was learned in Chem 110 is helping in current (sophomore) classes. A typical student response is the following quote.

The semester was very hard. I spent more time doing Chem 110 than I have spent on any one class yet. However, I also learned a great deal and my confidence greatly increased. The difficulty of the class also created a bond between the students that is helping in current classes.

1.3.2 Group Work Dysfunctional: Number of mentions = 4

Four students were coded as articulating that they did not like working collaboratively. This number included 5% of the SAL respondents (4) and no RL respondents. Typical of the 4 SAL student responses is the following quote.

The method of learning in 110 was definitely a new experience, but it did not work for me. Most of the year I felt as thought I were just fighting to keep up with the work and not learning as much as I know I could have. There were many times that I felt utterly helpless, frustrated, and stupid...Although I received an A in the class, it was not a happy or rewarding one.

1.4 Connections

The theme of "connections" is structured into two main areas; positive connections and negative connections.

1.4.1 Positive Connections: Number of mentions = 7

Seven comments were coded as articulating the point that positive connections were made. This number includes 9% of the SAL respondents (7) and no RL respondents. The SAL students either explained that the Chem 110 class made connections with the real world or helped them connect what they learned in Chem 110 with their current classes. Typical of the 7 SAL student responses are the following quotes.

1.4.1.1 Real World Connections

It was my hardest class I have ever taken (including Biocore & Organic Chem), but it was also the most satisfying. Prof. Wright integrated concepts with real-life experiments. Being able to design our own experiments really helped me understand material & have a sense of accomplishment!

My Chem 110 class was probably the best class I have had so far. It was experimental, focusing on group work and real-world applications, which made it useful and interesting. It was a lot of work, but I don't regret any of it.

1.4.1.2 Connections with current classes

When I finished the class I didn't necessarily understand the material, but now that I have had a couple months to digest it, I find that what I learned in the class is much clearer. I have used this knowledge to help others on my floor with their chemistry problems and I am really glad I took Chem 110 even if it was a lot harder then Chem 104.

1.4.2 Negative Connections: Number of mentions = 14

Fourteen students were coded as articulating the point that they failed to make connections in Chem 110. This number includes 4% of the SAL respondents (3) and 24% of the RL respondents (11). Students failed to see the connection between lecture and lab; between class and the real world, with the material or the concepts. No RL students mentioned connections in a positive manner. Typical of the 11 RL students responses are the following quotes.

1.4.2.1 Lack of Connection between Lecture and Lab

I learned a lot about setting up my own equations and applying them to new problems in lecture. Lab didn't seem to correlate with lecture at all and the few parts that did were done before we learned the concept in lecture. Lab was basically a separate course.

The thing that could have been improved was connecting lecture to lab. This may be a difficult task since Professors Woods approach is hard to reproduce in lab. Perhaps he can discuss some things that we will do in lab. This seems the most effective.

1.4.2.2 Lacked "Real World" Connections

Overall, it was very interesting because it was a difficult & therefore challenging course, but as for the real world applications I feel it was very poor. Students were taught an equation & what it meant, but never how to apply it. Moreover, it appeared as if we spent an entire semester on about two subjects.

1.4.2.3 Material seemed to lack connection, or "acontextual"

At times it was unclear the purpose of what we were learning, which would have helped to bring on better understanding. I think the purpose needs to be reinforced more often so it doesn't get lost in all of the details.

If anything, 110 caused me to change my major from Chemistry to Zoology. Talking to others, very little of the material covered in 110 will be of any use in later course work. Way too in-depth to be of much use.

1.4.2.4 Lack of Connections with Concepts

I think it was a waste of a semester for me. After memorizing all the equations last semester, I don't even understand the concepts behind them....

I felt that the class wasn't based enough in concepts.

Much too narrow - didn't learn how these specified problems related to other chemistry or analytical chemistry.

1.5 Confidence: Number of Mentions = 10

The theme of confidence was mentioned by students either positively or negatively. With confidence they soared and prospered as students. Without confidence they floundered and left chemistry. The number of positive "confidence" mentions is equal to the negative mentions.

1.5.1 Positive Confidence: Number of mentions = 5.

Five students were coded as articulating the point that Chem 110 was a confidence booster. This number included 7% of the SAL respondents (5), and no RL respondents. Typical of the 5 SAL student responses is the following quote.

Chem 110 was a pivotal course for me because I doubted whether or not I wanted to continue in my pre-med program. However, I wasn't sure I wanted to quit because I wasn't doing very well or because I truly liked another field better. By succeeding in Chem 110 I was able to make the right decision for myself. I wouldn't have succeeded w/o Professor Wright's caring, enthusiasm and virtually fool-proof learning technique. This course gave me back some self-confidence lost in Chem 109.

1.5.2 Negative Confidence: Number of mentions = 5.

Five students were coded as articulating the point that Chem 110 was a confidence booster. This number included 3% SAL respondents (2), and 6% RL respondents (3). Typical of the 5 student responses is the following quote.

While taking the course I severely doubted my level of intelligence because so much of the homework, labs, etc. was beyond my ability without the help of others. I felt that much of the material I should have had a better grasp on than I did. I felt surrounded by more intelligent people who had a lot better grasp on the material.

1.6 Chem 110 Experiences Overall

In respect to general Chem 110 experiences, students presented either overall positive or overall negative comments.

1.6.1 Positive Overall: Number of mentions = 29

Twenty-nine students were coded as articulating that on balance, Chem 110 was a positive experience. This number included 32% of the SAL respondents (24), and 11% of the RL respondents (5). Typical of the 24 SAL student responses are the following quotes.

I think I learned about 10x as much as I would have simply reading a textbook or listening to a professor lecture. Honestly, I <u>really</u> enjoyed the class and learned a lot. I was especially impacted by the interest Dr. Wright took in the students. Maybe it was the class structure or maybe it was Dr. Wright's enthusiasm, but I believe it was both that made me <u>really</u> enjoy Chem 110.

I really wish that organic chemistry would use this cooperative system. I learned so much. I felt like a number in that (o-chem) course and no one really cared if I did well. Chem 110 made me feel that the prof. really wanted me to learn. Chem 110 united the students. I see classmates now in other courses, we say hello & are really friends. The <u>best</u> part of this course is the friends you make! THIS SHOULD BE DONE EVERYWHERE!!

Chem 110 was a great experience for me. It taught me how to apply knowledge (not just memorize) and how to work with others. It was almost a let down to take a chem. class this semester that did not incorporate group learning to such an extent. I also made some really close friends from Chem 110!

Chem 110 is the best class and most rewarding I have had at this university.

My experiences in Chem 110 are only positive. Prof. Wright was wonderful and used his teaching style well. He demanded understanding of concepts and did his best to teach them.

Typical of the 5 RL student responses are the following quotes.
I thought Chem 110 was a great educational experience. I felt that it was taught with a unique and interesting approach to Chemistry and its analysis.

It was a tough class, required a lot of time and hard work. Solving problem was exciting if one could understand the concepts, otherwise it is a pain to solve those long problems.

*1.6.2 **Negative Experiences***: Number of mentions = 9

Nine students were coded as articulating that Chem 110 was a negative experience. This number included 9% of the SAL respondents (7), and 4% of the RL respondents (2). Typical of the 7 SAL student responses are the following quotes.

Basically, Chem 110 was a class that took up an unbelievable amount of time and basically resulted in no significant gain of knowledge. There were more problems in this class than benefits and to be completely honest, the best day of the semester was the day of our final exam.

This class took too much time and dropped my grades in other classes. I don't like spending 20-25 hours a week on a lab project.

In retrospect, I did not learn as much chemistry I thought I had. The take-home exams boosted my grade, but their difficulty limited the knowledge I gathered from them; losing points without an explanation of the covered method was not enlightening.

Typical of the 2 RL student responses is the following quote..

I felt it was a grand waste of time and energy. I am just glad I <u>somehow</u> managed a B (even though I flunked an exam or two).

Summary Comments:

Overall, RL students were less articulate about their Chem 110 experiences than SAL students.

- Both SAL and RL students agreed that this was an extremely time-consuming class.
- Among SAL students, accepting responsibility for one's own learning was a new experience and was generally valued.
- Group work: The low percentage of RL students who mentioned group work reflects the fact that any group work done by RL's was strictly voluntary and outside of class. But even that low percentage was positive about the rewards of group learning.

2. Analysis of Question about Long Term Effect of Group Work

"Regardless of how much you worked in groups in Chem 110, did your Chem 110 experience influence you to work in groups during this semester (Fall, 1995)?" *(Question 15)*
(N=115; 7 survey respondents left this question blank.)

With this open-ended question, we sought information about long term effects, if any, of group work in which students may have participated during Chem 110.

As many students said that Chem 110 influenced them to work in groups as sophomores as said it did not. Since RL students were neither encouraged nor expected to work in groups, it is to be expected that fewer of them were influenced by Chem 110 to work in groups.

Fifty-three students circled "yes," when asked if their Chem 110 experience influenced them to work in groups as sophomores. This number included 53% of the SAL respondents (40), and 28% of the RL respondents (13). Those students who said "yes" described 5 different effects; 1) more willing to work with others; 2) Chem 110 classmates are in current work groups; 3) working in groups was an opportunity to meet others; 4) group work helps them understand the material better; and 5) willingness to work with others is less strong this year.

2.1 More Willing to Work With Others: Number of mentions = 21

Of the 40 SAL mentions, 21 are grouped in this subcode, while 5 of the 13 RL mentions are grouped in this subcode.

I am more inclined to pursue a group and to see if they can help explain.

When possible.I try to work in groups. Chem 110 gave me a positive experience with it.

I always study in groups and in the lab I am in now, we work in groups some. I prefer it.

It influenced me to study more with other people and ask them their approach to problems.

It helped me realize that working in groups can be beneficial in ways.

I am more willing to work as a group to understand and solve problems.

I always work in groups to solve homework problems.

I found working in groups helps my understanding. I am more willing now to speak up.

Despite the fact that group work was not a required part of the RL curriculum, some students did find that working with others was beneficial. Typical of the 5 RL student responses are the following quotes.

I study in groups more often this semester.

My own study groups in 110 helped me, so this semester I have worked with others.

2.2 Chem 110 classmates are in current work groups: Number of mentions = 10
Of the 10 mentions grouped under this subcodes, 8 are by SAL students. (7 out of the 8 SAL students were females.)

I have worked with the people in my 110 lab section this semester. Groups-biocore/chemistry.

Many of the people in my lab worked together this semester in organic chemistry and biocore.

Being in Chem 110 influenced me. I work with my friend from 110 on assignments.

I found from Chem 110 other students that I worked well with, and continue to work with them.

Typical of the 2 RL student responses classed into this subcode is the following quote.

I knew people in class so I wanted to work with them.

2.3 Understand more: Number of mentions = 15
Students perceive themselves as obtaining a deeper level of understanding of sophomore course material as a result of Chem 110. They enjoy the brainstorming of a group. They see groups work as instilling confidence and leading to success. Typical of the 12 SAL student responses are the following.

I found working in groups helps my understanding. I am more willing now to speak up.

I realized that group work challenges me and is advantageous to my learning experience.

I know I learn better in cooperative learning. I can succeed on a much higher level.

I found working in a group brought many different ways of explaining one problem.

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Typical of the 3 RL student responses is the following quote.

I study and collaborate with others when studying to improve understanding.

2.4 Working in Groups Helped Me Meet Others: Number of mentions = 7.
Students appreciated the opportunity to meet and get to know other students. Typical of the 7 SAL responses grouped under this subcode are the following quotes.

Best part is students get to know one another. I made my best friend in college in this course.

Helped me to get to know others very well. These are people I can approach easily this semester.

The best part of 110 was getting to know people so well in lab, so I have found it fun.

2.5 Less Willing to Work in Groups. Number of mentions = 5
Since the SAL students were the ones who were required to work in groups, it is not surprising that they are the only ones who mentioned they are now less willing to work in groups. It appears that the students who didn't like working in groups, have very independent learning styles. Typical of the 5 SAL student responses are the following quotes.

I learned that I shouldn't work in groups because I personally don't learn that way.

I avoid groups unless I know the members will do work. I need to work by myself.

3. Analysis of Question on Work Best Suited for Groups

"What types of course work, if any, are better accomplished by student groups?" *(Question 16)*
(N=115; 7 survey respondents left this question blank.)

With this open-ended question, we sought information about the types of course work that students believe is best suited for group work.

Essentially all respondents (111 or 97%) said that certain kinds of course work were better accomplished by student groups. These responses mentioned 6 types of course work that are better accomplished by student groups: labs, difficult problem-solving, discussion, projects, homework, and math/science courses. Some responses are sufficiently complex that they were coded into more than one of these 6 categories.

3.1 Labs: Number of mentions = 41.

Forty-one students were coded as articulating that labs were better accomplished by student groups. This number includes 47% of the SAL respondents (36) and 11% of the RL respondents (5). Typical of the 36 SAL student responses are the following quotes.

Working together to solve a lab problem (laser attenuator) without step by step instruction made us learn that even with a lot of people working on it, the problem was not usually solved the first time.

Most lab work is great for group work too. Group work is good if it is used throughout a course on a regular basis.

Labs are and projects are better accomplished in groups.

I think labs and projects are better accomplished by groups.

Lab work can be if it is interactive enough. Writing lab reports together is oftentimes more trouble than its worth.

Big lab experiments that take weeks to complete and are open-ended and require much thought in experimenting - precisely the ones we did at they end of the semester.

I believe lab work is definitely better accomplished by student groups. Problem sets, also, are usually better accomplished in groups. It definitely is a test of your knowledge of the subject if you can explain it to someone else.

Typical of the 5 RL student responses are the following quotes.

I think that for most course work, it is good to have experience working in groups as well as individually. This includes science labs, writing assignments, oral presentations, etc.

I think labs are, because different people assume more interest and/or responsibility for different parts of the lab.

3.2 Difficult Problem Solving. Number of mentions = 39.

Thirty-nine students were coded as articulating that problem solving was better with groups. This number included 34% of the SAL respondents (26), and 28% of the RL respondents (13). Both SAL and RL students believed that working in groups was beneficial for problem solving. However, as the quotes below indicate, SAL students tend to emphasize groups enable multiple approaches to be shared, whereas RL students tend to emphasize groups enable distribution of data. Typical of the 26 SAL student responses are the following.

Difficult problems with many parts are great for groups because it provides many ways to solve the problems.

Definitely labs and difficult problem sets, especially when it is necessary to hypothesize different approaches.

Problem solving (e.g. Chem 110)....Seeing others points of view to strengthen your understanding. I would think over 1/2 of courses would go better this way!

Problems that are very challenging, or that have several different approaches.

Chemistry, Physics, Biology - group work helps with problem solving.

Problem solving and experimental set-up - for these things it is easier to work in groups because you (hear) a greater number of ideas floating around.

Difficult problem-solving, like the 110 labs, was good group work in general, I think.

That which requires problem solving. Memorization seems to be easily accomplished individually. Having the input of many seems to greatly help in approaching problems which may seem unfamiliar.

Typical of the 13 RL student responses are the following quotes.

Problem solving, i.e. addressing phenomena and theorizing on how to experimentally explain it.

Projects where one most come up with an experimental design, of if there is a huge problem were different people tackle different problems.

Learning new material and new problems because people can explain the parts they know and listen to others during the sections they don't understand well.

Detailed problems that have numerous parts. It helps to be able to distribute work between people when there is a lot of work to be done.

Problem solving and those involving a lot of communication for better understanding.

Definitely problem solving. Other things, such as reading or memorizing, are more individual. But a group can come up with more ideas for problem solving than a single person.

Creative thinking, complex problem solving, understanding.

3.3 Brainstorming: Number of mentions = 15

Fifteen students were coded as articulating the point that brainstorming was best accomplished with a group. This number included 9% of the SAL respondents (7), and 17% of the RL respondents (8). Typical of the 7 SAL student responses are the following quotes.

Brainstorming ideas for experimentation & solving problems that were really difficult (especially on take-home tests).

Typical of the 8 RL student responses are the following quotes.

When we are required to come up with many new, creative ideas, bouncing ideas off each other would facilitate thinking and creativity.

Students should first brainstorm and think for themselves about a certain topic and then discuss it in a group.

3.4 Projects: Number of mentions = 15

Fifteen students were coded as articulating the point that projects are best accomplished by groups. This number included 13% of the SAL respondents (10), and 11% of the RL respondents (5). Typical of the 10 SAL student responses are the following quotes.

Projects, especially lab based projects.

Labs and large projects that are helped by the integration of various points of view.

Typical of the 5 RL student response are the following quotes.

Projects which require a high degree of creativity & original thinking.

Projects where one must come up with an experimental design.

3.5 Homework. Number of mentions = 11

Eleven students were coded as articulating the point that homework was best accomplished by groups. This number included 7% of the SAL respondents (5), and 13% of the RL respondents (6). Typical of the 5 SAL student responses are the following quotes.

Groups are most valuable for completing very complicated, challenging questions (such as our home work and take-home exams) that require ways of thinking that not everyone has developed.

Typical of the 6 RL student responses are the following quotes.

Assignments with multiple parts because you might understand one part but not the other, while someone else may be the exact opposite.

Studying and homework.

3.6 Science. Number of mentions = 10

Ten students were coded as articulating the point that science courses, in general, would be best accomplished in groups. This number included 5% of the SAL respondents (4), and 13% of the RL respondents (6). Typical of the 4 SAL student responses are the following quotes.

I used to think group work was only applicable to humanities course work, but I have found it works just as well if not better in the sciences.

Typical of the 6 RL student responses are the following quotes.

Any of the sciences are always better working in groups.

Chemistry, Physics, Biology - group work helps with problem solving.

APPENDIX C

STATISTICAL ANALYSIS OF LIKERT SCALE SURVEY QUESTIONS[1]
CHEM110 FOLLOW-UP STUDY

Table C.1
Summary of Likert Scale Survey Constructs
Spring 1995 Chemistry 110 Alumni

Statistical Construct	Method	Modifier	p value	Average SAL Value	Average RL Value
1. Perceived Scientific Skills by Method	ANOVA		< .05	4.66	4.16
2. Confidence by Method	ANOVA		< .01	4.41	3.86
3. Agility by Method	ANOVA		<.001	4.39	3.61
4. Enjoyment of Science by Method	Loglinear	Score High	<.001	65.6%	29.4%
5. Perceived Ability to Connect Concepts and Applications by Method	Loglinear	Score High	<.001	85.7%	20.7%
6.a Perceived Ability to Work in Groups by Method (Men)	Loglinear	Score High	> .22	60.6%	37.5%
6.b Perceived Ability to Work in Groups by Method (Women)	Loglinear	Score High	< .05	81.5%	35.7%

Research questions

The primary research question that we addressed is whether the experimental "structured active learning" (SAL) instructional method in the second-semester, analytical chemistry course (Chem 110) affected students' perceptions of their competence in several areas. Because of non-random assignment to the two instructional methods, we partially controlled for differences in students' incoming characteristics by including in each analysis a measure of their gradepoint percentile in the prerequisite, introductory course (Chem 109). We also sought to ascertain whether any apparent effects differed for men and women.

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[1]Prepared by Leonard Springer, Ph.D.

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Data analysis

We began to analyze data from the student follow-up survey by creating six scales based on themes that students had previously identified as important: (1) students' enjoyment of science, (2) their perceived scientific skills, (3) their perceived ability to connect concepts and applications, (4) their perceived ability to work in groups, (5) their confidence, and (6) their agility (flexibility, versatility, or adaptability might also describe this construct). To retain the seven-point Likert item metric (where 0=strongly disagree and 6=strongly agree), we calculated each scale by summing the item scores and dividing by the number of items. Table 1 presents the scale names and items comprising the scales.

After creating the scales, we evaluated the extent to which each scale represented the construct that it was intended to measure by calculating Cronbach's alpha, a coefficient of internal consistency reliability. Cronbach's alpha is based on the average correlation of items on each scale. One might interpret the coefficient as the squared correlation between the observed score on a scale and the score an individual would have received if questioned on all possible items that measure the same construct (a hypothetical "true score"). Table 1 reports that the alphas for the six scales range from .76 for our measure of students' confidence to .94 for our measure of students'perceived ability to work in groups, suggesting that the scales adequately represent the constructs of interest.

Because our choice of analytical technique depended upon distributional assumptions, we next tested the distribution of the data. Table 1 also reports the results of the Kolmogorov-Smirnov (K-S) test, with a Lilliefors significance level greater than .05 required to infer a normal distribution. The scales reflecting students' scientific skills, confidence, and agility appear to be normally distributed. Thus, we chose analysis of variance (ANOVA) techniques to evaluate these three scales and loglinear analyses to evaluate the remaining scales.

For each three-way ANOVA and loglinear analysis, we modeled instructional method (experimental = 1, control = 2), Chem 109 gradepoint percentile (1 through 8 interval), and gender (female = 0, male = 1) as main effects in addition to each two- and three-way interaction. For the loglinear analyses, we categorized data for each scale to represent low (1 and 2) medium (3 and 4) and high (5 and 6) scores. We removed measures of non-significant effects ($p>.05$) until each model was as parsimonious as possible. We then evaluated how well the model fit the data and interpreted the substantive significance of the results.

Results

The ANOVAs for the scales measuring students' perceived scientific skills, confidence, and agility all showed statistically significant instructional method effects. Students in the experimental "structured active learning" (SAL) group tended to score higher on the three measures than those in the "responsive lecturing" (RL) control group. We illustrate these

differences in Figures 1 through 3. No other main effects or interactions were significantly related to these three scales. The difference in instructional method explained 5.1 percent of the variance in students' perceived scientific skills ($F = 5.845$; $df = 1, 109$; $p<.05$), 7.4 percent of the variance in their confidence ($F = 7{,}859$; $df = 1, 109$; $p<.01$), and 13.0 percent of the variance in their agility ($F = 15.677$; $df = 1, 105$; $p<.001$).

The loglinear analyses produced similar results, with each scale, the instructional method, and their interaction appearing as statistically significant. Students who participated in SAL were more likely to score high and less likely to score low on these scales than were their counterparts in the RL control group. We present these differences in Figures 4 through 7. For example, Figure 5 indicates that 85.7 percent of SAL students score high (5 or 6 on the 6-point Likert scale, where 1=disagree and 6=agree) in their perceived ability to connect concepts and applications, compared with 20.7 percent of RL students. Likelihood-ratio chi-square goodness-of-fit statistics (L^2) indicate that each model fit the data quite well: students' perceived ability to connect concepts and their application ($L^2 = 68.68$, $df = 90$, $p = .954$), their enjoyment of science ($L^2 = 81.25$, $df = 90$, $p = .734$), and their perceived ability to work in groups ($L^2 = 95.90$, $df = 88$, $p = .265$). Only one three-way interaction was significant: students' ability to work in groups, instructional method, and gender. Women who participated in SAL reported greater ability to work in groups than women who participated in RL ($p<.05$), although this difference was not apparent for men ($p>.22$).

Table 1.

Scales for Assessing the Effects of Instructional Method.

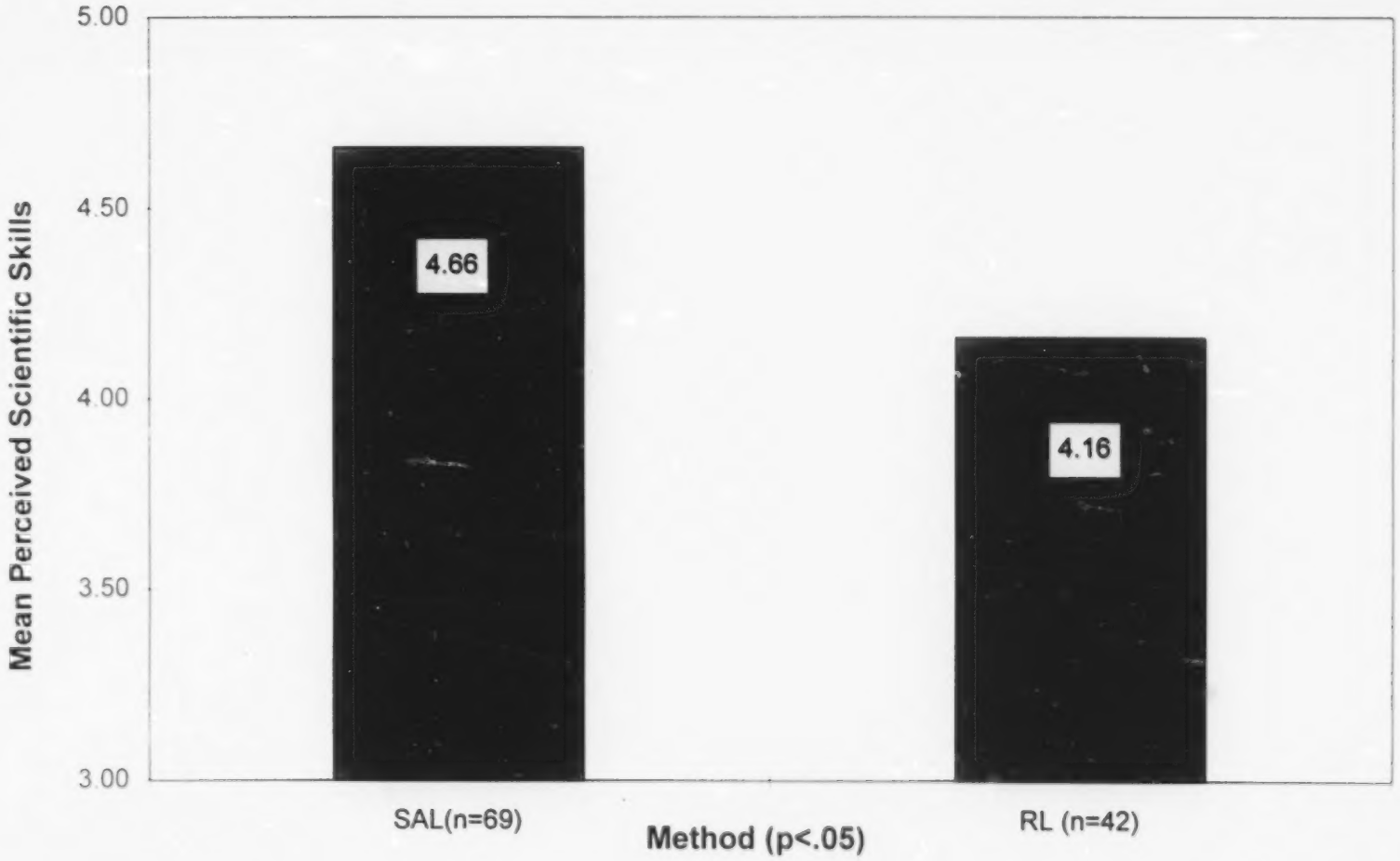
Scale/Item	Reliability[a]	Distribution[b]
1. Enjoyment of Science	.88	.10*
Chem 110 engaged my interest and raised my enthusiasm for chemistry.		
Most aspects of Chem 110 were intellectually exciting.		
2. Perceived Scientific Skills	.86	.08
I feel the teaching method used in this course increased		
my skills in problem solving.		
my skills in experimentation.		
As a result of my Chem 110 course I am:		
able to set up equations.		
able to set up an experiment.		
able to solve equations.		
3. Perceived Ability to Connect Concepts and Applications	.81	.10**
Chem 110 helped me understand how to apply chemistry to real world issues.		
In this course I discovered the value/use of concepts by utilizing them to solve problems.		
In this course I was able to integrate what I learned in lecture and lab.		
4. Perceived Ability to Work in Groups	.94	.12***
As a result of my Chem 110 course I am:		
more interested in working with others to complete coursework.		
more able to work with others productively.		

Table 1. Scales for Assessing the Effects of Instructional Method (Continued).

Scale/Item	Reliability[a]	Distribution[b]
5. Confidence	.76	.05
Chem 110 instilled confidence in my ability to succeed in other science courses.		
As a result of my Chem 110 course I am:		
more willing to critique my own work.		
more willing to critique others' work.		
inclined to stick with problems longer before seeking help or giving up.		
6. Agility		
As a result of my Chem 110 course I am:	.81	.07
more willing to try other ways of thinking and learning.		
more comfortable with learning in new ways.		
Chem 110 made me feel more comfortable with cross-disciplinary ways of thinking.		
The course structure left me confused about what I was to know.[c]		

[a]Cronbach's Alpha.
[b]Kolmogorov-Smirnov (K-S) statistic with a Lilliefors significance level for testing non-normality.
[c]Item reverse coded.
*$p<.05$. **$p<.01$. ***$p<.001$.

Figure 1. Perceived Scientific Skills by Method



Note Six-point scale where 1=disagree and 6=agree

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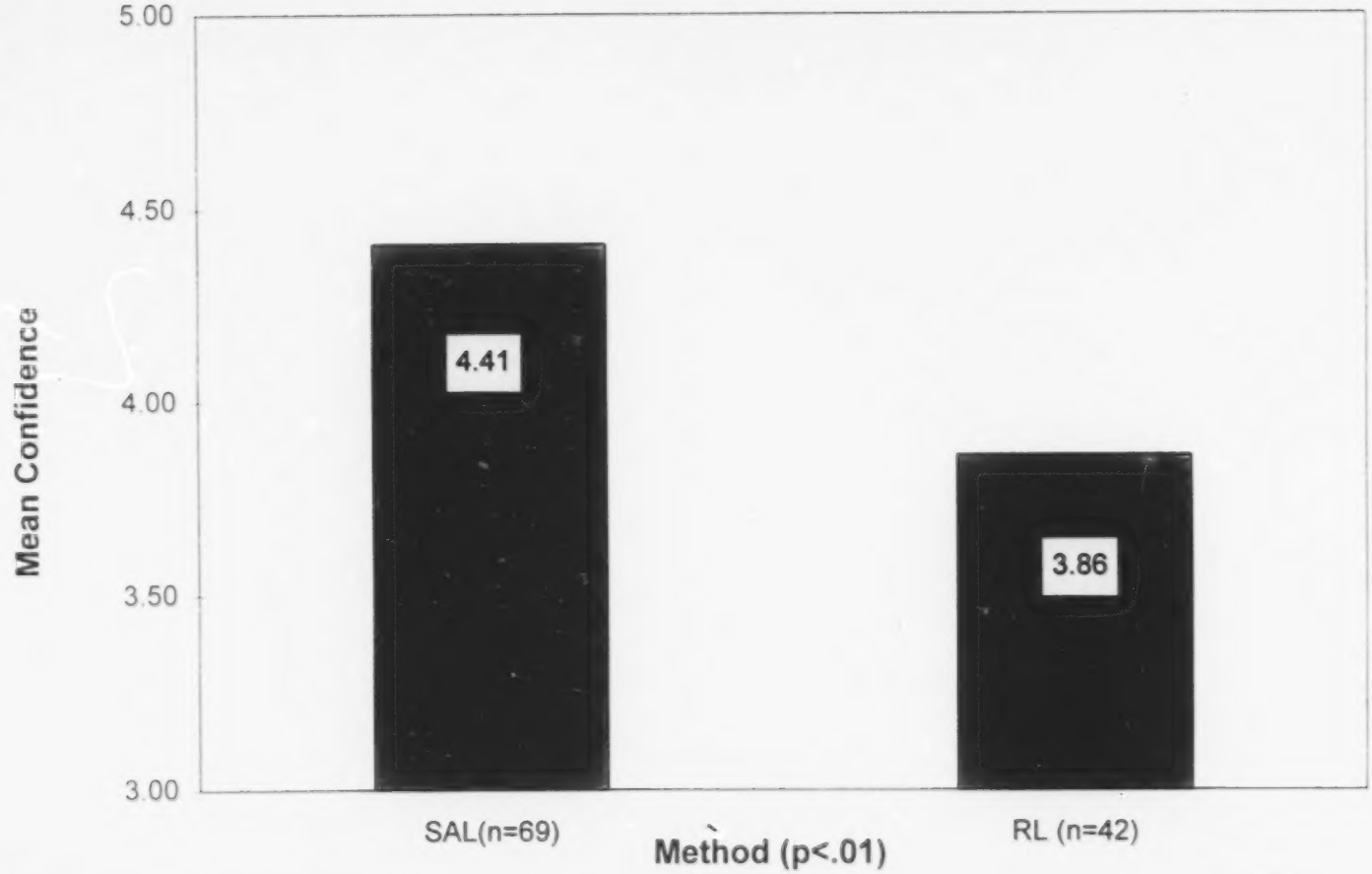
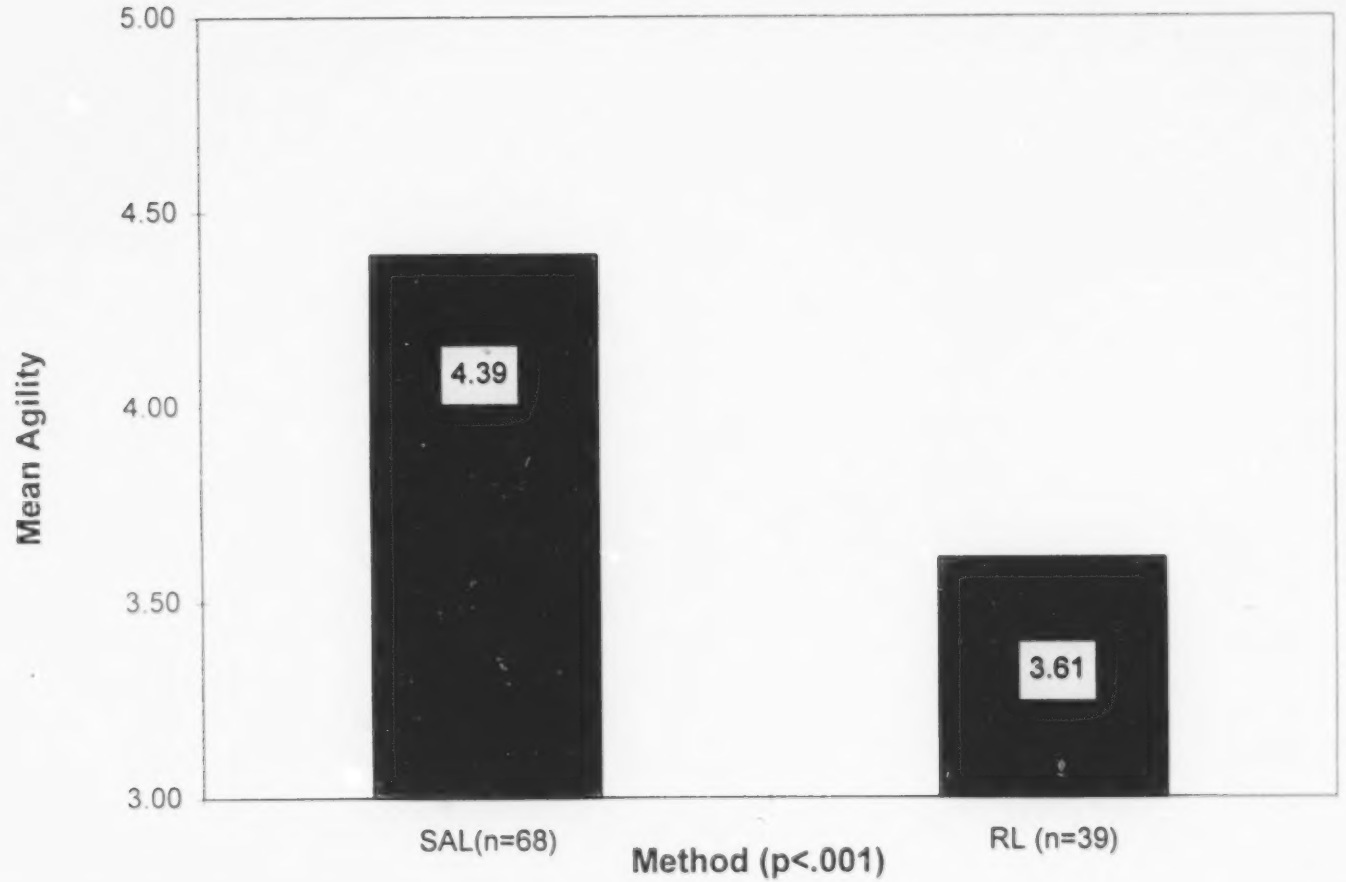
Figure 2. Confidence by Method



Note. Six-point scale where 1=disagree and 6=agree.

Figure 3. Agility by Method



Note. Six-point scale where 1=disagree and 6=agree.

Figure 4. Enjoyment of Science by Method

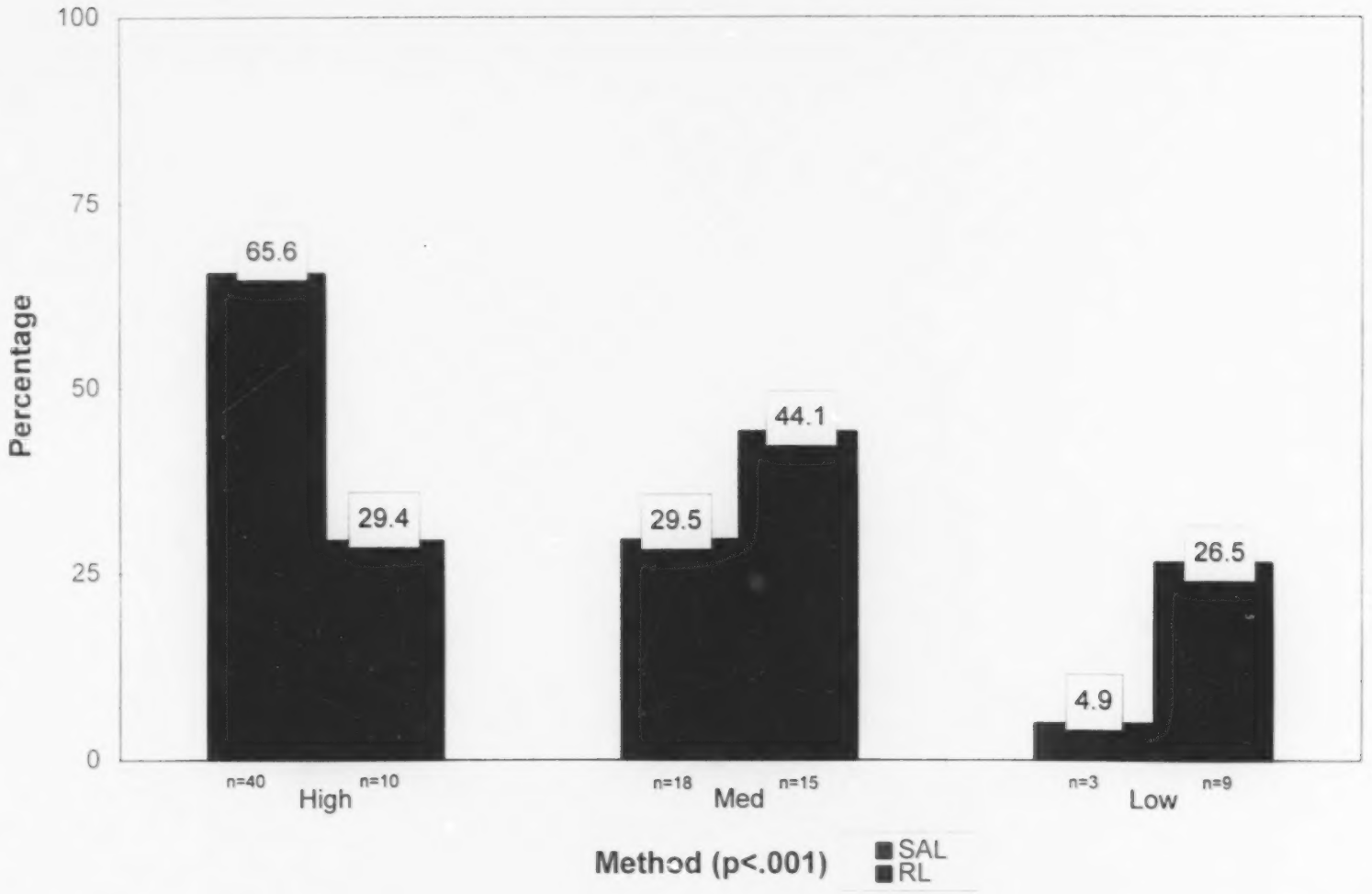


Figure 5. Perceived Ability to Connect Concepts and Applications by Method

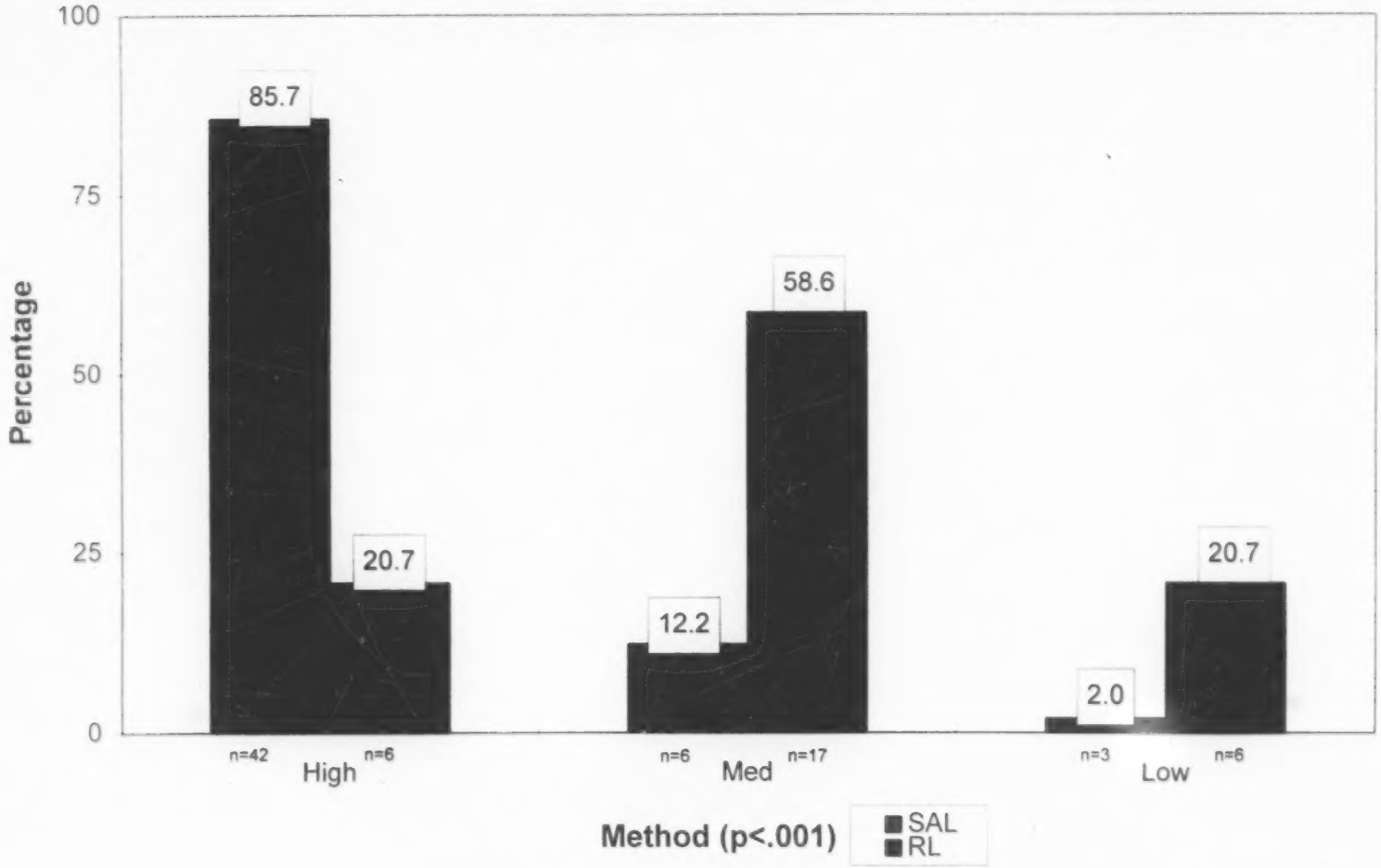


Figure 6. Perceived Ability to Work in Groups by Method (Men)

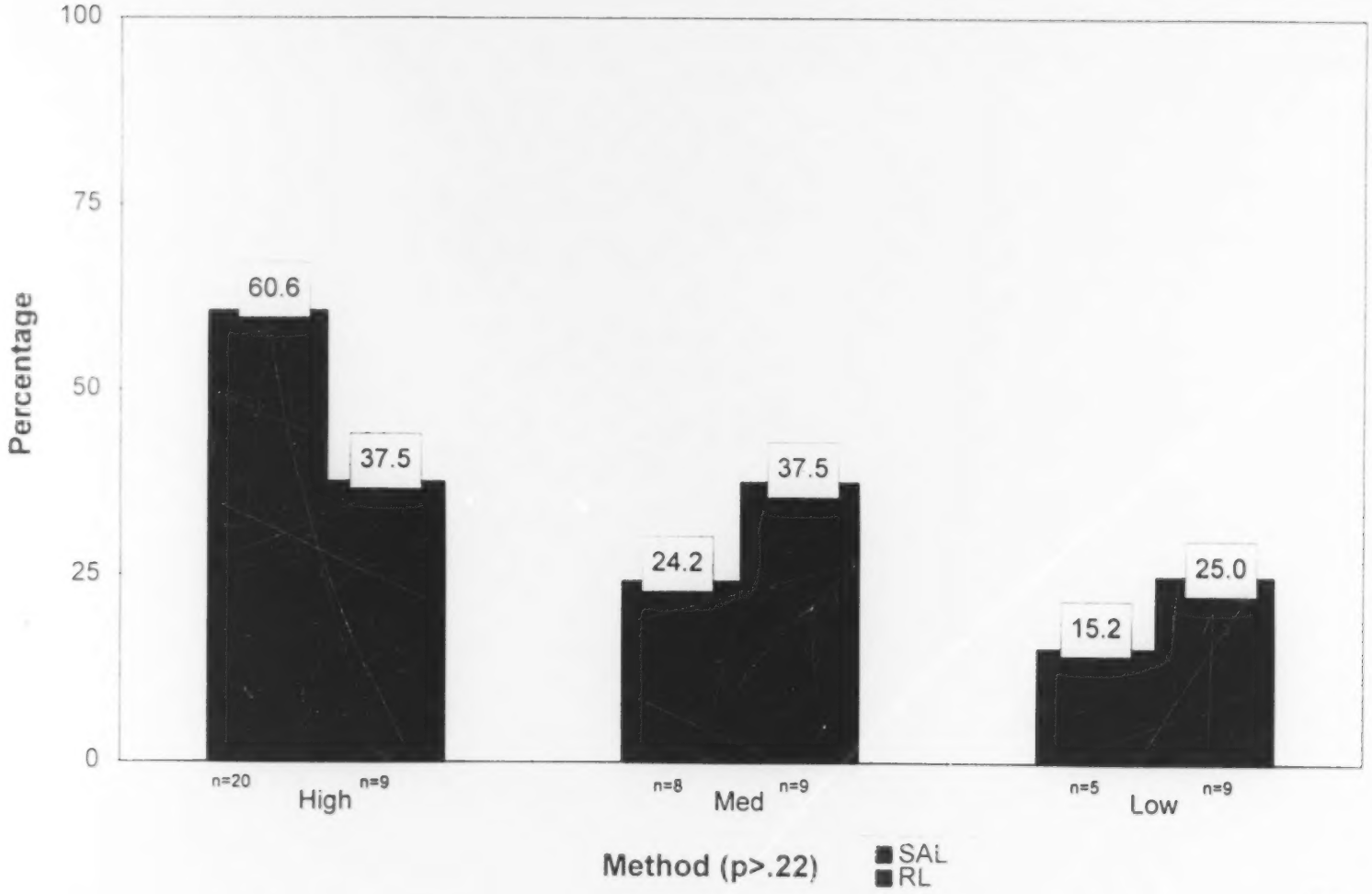
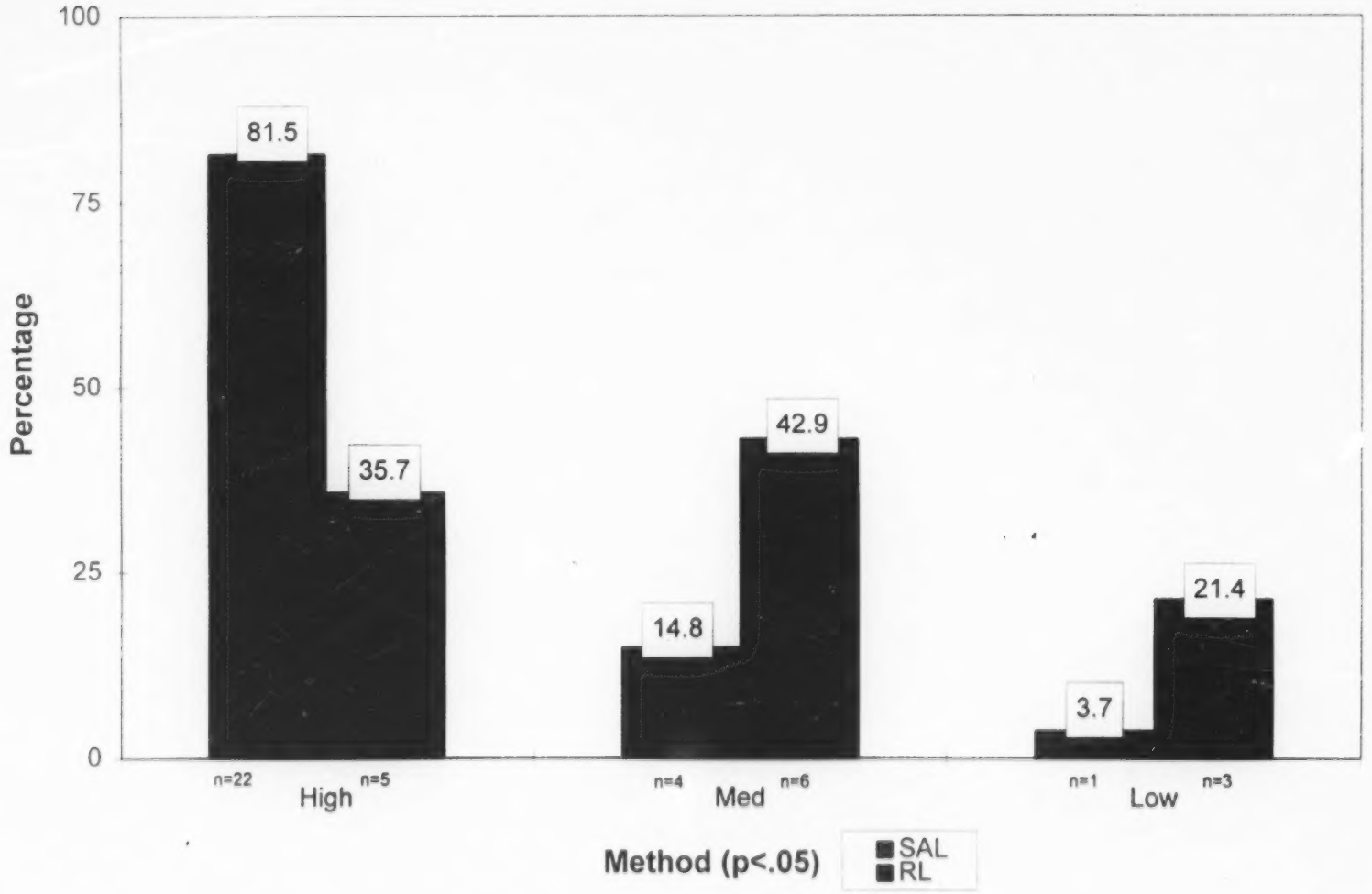


Figure 7. Perceived Ability to Work in Groups by Method (Women)



APPENDIX D

Effects of the Oral Exam Administered by the Faculty Assessors

Both SAL and RL student have experiences of making connections salient. For the first time that semester many students made the connections between what they learned in Chem 110 to other aspects of their world.

1. Personal Connections with Professor

For different reasons students valued the connection they had with their assessor.

Meeting professor viewed as useful. A few students saw meeting a professor and spending one-on-one time "cool". They enjoyed the personal connections to view the professor as 3-dimensional person rather than a one-dimensional authoritative or dictatorial head standing in front of a lecture podium. This was especially true for the RL students. SAL students seemed to have more access or felt they had more access to their professor. Below is a quote is typical for a RL student.

> *I was glad I did it just because the professor I had was really nice and he was interested in me and he found out that I wanted, that I was considering a biochem major. He offered me all this help, he was like, "Next year when you come in, you know, if you need a lab job, come to me, I'll be kind of an unofficial advisor". So I was more glad in general meeting a professor and just talking to them and seeing that, yeah, some of them can be nice and helpful.*

Both SAL and RL students had a chance to explore diverse engineering fields while enjoying interaction with professor. A few students recast the oral exam as an opportunity for them to explore diverse fields. The following quotes are typical for both SAL and RL students.

> *I enjoyed the exam itself and the interaction with the professors…Because I think it gave me - that interview gave me some real good ideas on whether or not I would be interested in biochemistry.*
>
> ********
>
> *For instance, those oral exams we had. Like the one I had with the pharmaceutical professor, I had no idea. Coming in, she's a professor. Had her own lab, and she actually took me into her lab. That was like the biggest thing. The biggest impression I had. All these lines going around. Come on, that's pretty neat. This is what she's studying and everything. I had no idea what to expect of it. Yet, I could kind of walk my way through it a little bit, so I guess it helped you in that sense. Just become more well rounded. All classes should do that in some sort of way.*

For a subset of students, the oral exam was a valued connection to a professor while also an academic connection showing the student how chemistry is used:

> *I think for me it was meeting the professor and seeing a field that before than I had never even heard of before except for you know, what it said in the timetables. So it kind of gave me a real link with a professor. But the exam itself was more showing me how it's used rather than quizzing me so much on material, I thought. It was more like /an extension of it....It had a base in the Chemistry 110 things. And it went on to things applicable to his department. Which I thought was good.*

One SAL student actually stayed in chemical engineering on the recommendation of one of the assessors. This student was influenced by the professor as illustrated below.

> *Actually, the class made me think about transferring out of chemical engineering.... but then, when I went through that comprehensive knowledge interview, the math prof actually told me not to go to a straight math major, and to stick with Chem E. That's why I'm still in it.*

2. Academic Connections

2.1 Lab work valued by RL students

RL students recounted that lab work was useful for what they needed to do in the orals. It was an entirely new experience for these students to have a context sensitive applied questions, which made the value of lab more apparent. These questions helped RL students make connections and in turn these connections allowed the student to reason for him/herself:

> *I also had a pharmaceutical professor. The questions she asked me were general chemistry based. I would say, having more to do with Chem 110 lab than with lecture, but I didn't think the lecture and lab in Chem 110 were related in any way, shape or form, but the questions I thought she put them out there and the vaguest sense of the term, just gave me the groundwork. And it was something I'd never encountered before, it had to do with her work. I would say, which I had no dealings with and then it was more of a, just a general knowledge of chemistry that helped me get along and kind of reason it out. But I wouldn't say, in terms of, I guess, in terms of 110 helping me, deduce the problem, I would say that the lab more than the lecture was more pertinent to what she asked me....We can't be just regurgitating the same information we were taught, since they had no idea what that was. So, but what she did, relating practical chemistry to her work was pretty much, was pretty much what I thought it would be.*

I was glad I did it because I think it was the first time chemistry made me think on my own. I'd never been through, two semesters of chemistry. Maybe in the labs once and a while, you kind of figure things out on your own, but generally it's pretty much spoon fed to you, and you have to give it back. So this was the first time when I went in there with no knowledge of what I was going to be asked. I had to kind of scare it together.

2.2 Learning by Explaining

Many SAL students expressed that the oral exam was an opportunity to apply learning through the experience of explaining to someone else. This "oral" concept helped them realize academic connections they had made in Chem 110. This also allowed the oral exam to be a validating learning experience. Below are a few typical quotes by male SAL students.

[The oral exam] complemented my ability to explain it to somebody else, the fact that I knew what I was doing.

****

You just went in there and tossed around ideas. I liked it because it showed me what I learned in 110 was applicable. Even if just a little bit, that it was worth it. I didn't think it was a quiz at all. I kind of liked it…It was just kind of a learning experience to see how we use everything we learn.

****

I liked being able to explain myself rather than just take some written exam that was really set in stone, I could really explain why I'm breaking down what I'm breaking down with the oral.

****

It kind of helped me, because if I can explain something to someone else then I have a pretty good understanding of it. It helped me know what I do and what I didn't know.

****

My experience was that [the faculty assessor] just sat down and talked to us, or, talked to me, and drew some things out on paper and had me explain things and try to relate what I knew to - what I got from the class to other things here.

APPENDIX E
LEAD Center
Follow-Up Assessment and Evaluation of Chemistry 110
Student Focus Group Interview Protocol
Fall 1995

Introductions

Present Informed Consent Form. Briefly review points from the consent form.

Questions

A. Follow-Up - Oral Exam

I am going to ask you to think back to May of this year. Tell me, do you remember how you felt about your oral exam?

Was it what you expected?
--(Were you surprised, comfortable, ill at ease, on the same wave-length as professor?)

What, if anything, did you get out of taking an oral exam?

B. Effects of Collaborative Learning

Last semester those of you in Professor Wrights Chem 110 class had a lot of required group or team work activities. While the other students from Professor Woods Chem 110 class either worked alone or maybe with other students (volunteer cooperative learning). This could include meeting other classmates at the library or a coffee shop to work on homework or a take-home exam.

If you were engaged in collaborative or active learning in Chem 110 what effects, if any, did it have for you?
--last semester?
--this semester?
--other classes?
--outside the classroom?

Have you had any other classes involving required group or team work activities? (Either this semester or past semesters?)
--how effective. why? or why not?

What are the benefits or problems of working in groups? Be specific.(probe for issues raised by shared tasks or assignments--e.g., "being held back", "cheating", better understanding of concepts?)

If there were any problems with groups with which you worked, did you find ways around them? How?

Do they think groups are better for some purposes than others? Explain.

C. Effects of Chemistry 110 Overall on Academic Program

Of your Chem 110 experience overall, what aspects, if any, are helpful or a hindrance in your current classes?

--Was the curriculum of Chem 110 too narrow, just right, or too broad? Can you give specifics?
--Anything about the TA or professor?
--Anything about the way you were assessed and the grading process?
--Are you able to see the linkages between different topics by using the concepts you learned in Chem 110 to understand them?

Are there any effects of the course, overall, on you as a student?

--Do you think you will be able to apply what you learned in Chem 110 to your future coursework?
--Any effect on your choice of future courses, major, professional interest?

D. Effects of Chemistry 110 for You as a Science-Educated Citizen

You may recall, we asked you this next question last time. We are interested in knowing if you thoughts have changed since the last time we talked. In what ways has your understanding of chemistry changed your perceptions of:
a) your day to day life
b) industrial society (e.g. industrial, agricultural, medical production...)
c) the environment (e.g. pollution, agriculture, water quality....)
d) nature
e) science

Overall, what effects, if any, has Chem 110 had on you as an science-educated individual?

How do you relate to chemistry now? Do you make different mental connections than you did last year? Please relate to specifics about the course, if possible. (Positive/Negative).

E. Applicability to Current Academic Learning Patterns

We know from research that a good portion of student learning occurs outside the classroom. As a student, where does "meaningful learning" take place? (Can be anywhere; a coffeeshop, your dorm room, while camping, etc....)

Think of the most difficult problem you had this semester. How did you go about solving it? (What resources did you use? Friends, library, TA, Professor, etc.)

F. Closure

Do you have issues or concerns about Chem 110 that you would like to discuss?

Is there anything else particularly interesting, surprising, valuable, pleasing or disappointing about the course that you would like to relate?

Do you have any questions or comments that you would like to share with me?

APPENDIX F
CHEMISTRY 110 FOLLOW-UP SURVEY

Instructions: The questions in this survey are intended to help LEAD Center researchers understand your experience in Chemistry 110 during Spring 1995. All responses to these surveys will be kept confidential. The LEAD Center will report only summarized conclusions in which individual student's viewpoints cannot be identified. Please complete the survey as soon as possible return it to the LEAD Center in the enclosed stamped self-addressed envelope.

Your name _____ Gender _____

Chem 110 Lecture section (**please circle**) Wood Wright

Using a scale of 1 to 6, where 1 means "disagree" and 6 means "agree," please circle the number which most approximates your view **as a result of taking Chem 110. (Circle one number**).

		Disagree					**Agree**
Q1.	CHEM 110:						
	a. engaged my interest and raised my enthusiasm for chemistry	1	2	3	4	5	6
	b. was well organized	1	2	3	4	5	6
	c. required me to ask why, to explain	1	2	3	4	5	6
	d. helped me understand how to apply chemistry to real world issues	1	2	3	4	5	6
	e. instilled confidence in my ability to succeed in other science courses	1	2	3	4	5	6
Q2.	Most aspects of Chem 110 were intellectually exciting.	1	2	3	4	5	6
Q3.	I learned more in this course than in any other course I have taken at the UW-Madison.	1	2	3	4	5	6
Q4.	In this course I discovered the value/use of concepts by utilizing them to solve problems.	1	2	3	4	5	6
Q5.	In this course I was able to integrate what I learned in lecture and lab.	1	2	3	4	5	6

(OVER)

		Disagree					Agree
Q6.	I felt rushed in this course.	1	2	3	4	5	6
Q7.	This course led me to believe that students need to take major responsibility for their learning.	1	2	3	4	5	6
Q8.	Chem 110 made me feel more comfortable with cross-disciplinary ways of thinking.	1	2	3	4	5	6
Q9.	The course structure left me confused about what I was to know.	1	2	3	4	5	6
Q10.	I feel the teaching methods used in this course increased						
	a. my skills in problem solving.	1	2	3	4	5	6
	b. my skills in experimentation.	1	2	3	4	5	6
Q11.	As a result of my Chem 110 course I am:						
	a. more willing to try other ways of thinking and learning	1	2	3	4	5	6
	b. more interested in working with others to complete coursework	1	2	3	4	5	6
	c. more able to work with others productively	1	2	3	4	5	6
	d. more comfortable with learning in new ways	1	2	3	4	5	6
	e. more willing to critique my own work	1	2	3	4	5	6
	f. more willing to critique others' work	1	2	3	4	5	6
	g. inclined to stick with problems longer before seeking help or giving up	1	2	3	4	5	6
	h. able to set up equations	1	2	3	4	5	6
	i. able to set up an experiment	1	2	3	4	5	6
	j. able to solve equations	1	2	3	4	5	6

Q12. I found that the following aspects of Chem 110 helped me learn and understand the course material well enough to retain it:

	Disagree					Agree	Not Applicable
a. lectures	1	2	3	4	5	6	NA
b. discussion section	1	2	3	4	5	6	NA
c. hands-on experience (includes lab)	1	2	3	4	5	6	NA
d. computer use/technology	1	2	3	4	5	6	NA
e. working independently and asking the professor when I need help	1	2	3	4	5	6	NA
f. working independently and asking the TA when I need help	1	2	3	4	5	6	NA
g. exploring and discovering things for myself	1	2	3	4	5	6	NA
h. exploring and discovering things with one other person	1	2	3	4	5	6	NA
i. exploring and discovering things with a group	1	2	3	4	5	6	NA

Q13. In Chem 110, did you work in groups?

NO
YES If yes, were there problems with the groups you were part of?

Q14. NO
YES If yes, please describe these problems and explain what, if anything, you did to address them.

(OVER)

Q15. Regardless of how much you worked in groups in Chem 110, did your Chem 110 experience influence you to work in groups during this semester (fall 1995)?

NO

YES If yes, please explain.

Q16. What types of coursework, if any, are better accomplished by student groups?

Q17. Do you believe that a teacher should use a variety of techniques in order to suit different learning styles?

NO

YES If yes, please explain.

Q18. Looking back on your Spring 1995 semester, please comment on your experiences in Chemistry 110, using the lines below.

Thank you very much for your time and attention!